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[THIRD SERIES.]

ART. LV.—*An Experimental Comparison of Formulæ for Total Radiation between 15° C. and 110° C.;* by W. LECONTE STEVENS.

THE earliest attempt to express the rate of cooling of a heated body was that made by Newton and embodied in a simple formula, which states that this rate is directly proportional to the difference of temperature between the radiating body and the medium surrounding it. It has long been known that this law is only approximately true when these temperature-differences are small, and that it is wholly inapplicable when they are large.

During the early part of the present century an elaborate research on the measurement of temperature and the communication of heat was made by Dulong and Petit.* Such instruments as the thermopile, the bolometer, and the galvanometer had not yet been invented. Their method was to employ as radiating body a large thermometer whose bulb contained more than a kilogram of mercury. This was placed within an envelope which was kept at constant temperature and made nearly vacuous as quickly as possible after the introduction of the heated bulb. The rate of cooling was found to be a function of the temperature of the envelope, the latter being kept constant during any given experiment, but varied for different experiments. For a given difference of temperature between the bulb and its enclosure it was found that the rate of radiation increases very nearly in geometrical progression while that of the enclosure increases in arithmetical progression. If

* Annales de Chimie et de Physique, vol. vii, 1817.

S represent the quantity of heat radiated in unit of time, θ the temperature of the enclosure, t the excess of temperature of the radiating body over that of the enclosure, a a constant whose value they determined to be 1·0077, and m another constant whose value depends on the nature of the substance and the condition of its surface, the law of Dulong and Petit is expressed by the formula

$$S = m(a)^{\theta}(a^{t}-1) \qquad (1)$$

In order to compare this formula with others presently to be given, it will be best to express θ and t in terms of absolute temperature. Letting T stand for the absolute temperature of the heated body, and T_0 that of the enclosure, we have $\theta = T_0 - 273$, and $t = T - T_0$. The formula now becomes

$$S = m(1{\cdot}0077)^{T_0-273}(1{\cdot}0077^{T-T_0}-1) \qquad (2)$$

The range through which the value of $T-T_0$ was varied in these experiments was 240° C., while the temperature of the enclosure was varied from 0° to 60° C.

Subsequent investigators have tested the formula of Dulong and Petit, and have found that although it may seem to correspond nearly to the truth within the limits selected, it gives very erroneous results at higher temperatures, the radiation revealed by measurement being much less than that which is calculated by means of the formula. De la Provostaye and Desains tested it with thermometers whose bulbs were covered with a plating of metal, and found that under this condition the factor, m, varies with the temperature.* Draper, Tyndall, and Ericsson have published researches which showed the insufficiency of Dulong and Petit's formula. This formula may therefore be considered now as of only historic interest.

In an exhaustive comparison of the work done by these physicists, Professor Stefan, of Vienna, proposed a formula which, like those that preceded it, is empirical, but which corresponds much more nearly to the results of measurement than does that of Dulong and Petit.† He found that the amount of heat emitted in unit of time was proportional to the fourth power of the absolute temperature; or, in the notation already employed,

$$S = mT^{4} \qquad (3)$$

Since there is an exchange of heat between the radiating body and the surrounding medium, the effective radiation is

$$S = mT^{4} - mT_0^{4}$$

This is obviously reducible to the form

* Ann. de Chimie et de Physique, III, xvi.

† Sitzungsberichte der K. Akademie der Wissenschaften, Wien, lxxix, 1879.

$$S = mT_0^4\left(\frac{T^4}{T_0^4} - 1\right) \qquad (4)$$

This formula has the advantage of great simplicity and ease of application.

Almost simultaneously with the publication of Stefan's paper in Vienna appeared an experimental research on the temperature of the sun, by M. F. Rosetti, of Padua.* Rosetti employed the thermopile and galvanometer for measuring the radiation from a Leslie cube covered with lamp-black and filled with water, which was stirred in order to secure uniformity. For temperatures between 100° and 300° mercury was substituted for water. In the liquid were immersed the bulbs of two thermometers whose readings gave the mean temperature at any selected moment. For still higher temperatures a copper ball was heated to redness, then exposed at a fixed distance in front of the thermopile long enough to produce a galvanometer deflection, and immediately afterward thrown into a calorimeter. The specific heat of copper being known, it becomes possible to compute the temperature of the ball at the moment of its immersion in the water. From these and other experiments Rosetti was led to adopt the empirical formula,

$$S = aT^2(T - T_0) - b(T - T_0) \qquad (5)$$

Here a and b are two constants whose values for the particular instruments he employed were determined to be $a = 0{\cdot}00000335131$, and $b = 0{\cdot}0636853$. Rosetti considered the first term of his formula to represent the heating effect if the body were radiating in a vacuum, and the second term to represent the radiation of the air in which the body is immersed. Comparing this with Newton's formula,

$$S = a(T - T_0),$$

it is seen that while Newton regarded the emissive power, a, as independent of temperature, Rosetti regarded it as proportional to the square of the absolute temperature.

The accordance between the results of experiment and of calculation by means of this formula, as published by Rosetti, are quite remarkable, though the experiments seem liable to some criticism. Any assumptions regarding the uniformity of temperature in a Leslie cube are subject to challenge, if the water be not kept boiling. The calculations of temperature from calorimetric measurements is usually affected with a large probable error. For temperatures higher than those employed in calorimetry Rosetti used small disks of metal which were rendered incandescent in the hottest flames at his command,

* Annales de Chimie et de Physique, V, vol. xvii, 1879.

and their radiation while thus glowing was measured by means of the thermopile. Finding his formula apparently satisfactory, he assumed it to be applicable to yet higher temperatures. Exposing his thermopile to the sun and comparing the deflection thus obtained with that given by a body of known temperature and area, at a known distance, the temperature of the sun was computed to be about 10,000° C. The work done by Rosetti was valuable; but his formula, involving two undetermined constants which vary with every thermometric instrument employed, may be considered, like that of Dulong and Petit, as of little more than historic interest.

In 1888 an important communication regarding the radiation of solid bodies was given to the Berlin Academy of Sciences by Professor H. F. Weber, of Zürich.* He had been engaged in an extended investigation of incandescent electric lamps for the purpose of finding, if possible, a general formula for the relation existing between the quantity of light emitted, the area of the radiating surface, the quality of the substance raised to incandescence, and the amount of electric energy expended. Among the results attained was the establishment of a formula expressing the relation between the intensity of any selected homogeneous radiation, the corresponding wave length, the temperature, and the quality of the radiating substance. An indispensable factor in the determination of this formula was the previous admirable work of Langley on radiation from the sun and various terrestrial sources, expressed in an energy curve which is now familiar to all physicists. From the study of this energy curve and of all other published results that were accessible, as well as his own experiments, Weber obtained the following formula:

$$s = c\pi F \frac{1}{\lambda^5} e^{aT - \frac{1}{b^2 T^2 \lambda^2}}$$

Here T denotes the absolute temperature of the radiating body, expressed in degrees centigrade, λ the wave length of the homogeneous radiation considered, F the area of the radiating surface in square centimeters, e the base of the Naperian system of logarithms, and s the amount of energy radiated by the body in all directions in unit of time. The constant, c, depends on the nature of the radiating surface; it is the "emission constant." The constant b^2 depends also on the nature of the radiating body. Its mean value, as determined from a large number of experiments has been found to be

$$b^2 = 0{\cdot}196 \times 10^{-6}$$

* Sitzungsberichte der K. Akademie der Wissenschaften, Berlin, 26 Juli, 1888.

To determine the value of the constant a, experiments were made upon a variety of solid conductors, including carbon, platinum, iron, and copper, raised to incandescence. For each of these the same value was found,

$$a = 0{\cdot}0043$$

If it be desired to find the total radiation, rather than that of a single wave-length, the equation just given must be integrated between the limits $\lambda = 0$ and $\lambda = \infty$. We have then for the total radiation, S,

$$S = \int_0^\infty s d\lambda$$

The result of the integration is

$$S = \tfrac{1}{2}\pi\sqrt{\pi}\, cbFe^{aT}T$$

Or, letting C represent the total emission constant, $\frac{1}{2}\pi\sqrt{\pi}\, cb$, we have

$$S = CFe^{aT}T$$

If the radiating body be surrounded by another body whose constant absolute temperature we may call T_0, there is mutual radiation between the two, and the resultant radiation of the first becomes

$$S = CFe^{aT}T - CFe^{aT_0}T_0$$

This is obviously reducible to the form

$$S = CFe^{aT_0}T_0\left(\frac{T}{T_0}e^{a(T-T_0)} - 1\right)$$

Here the quantity outside of the parenthesis is made up of constants, and the variation of S is dependent only on T. For purposes of comparison therefore we may employ only what is found within the parenthesis.

This formula has been tested by applying it to the results of experiments already published by Schleiermacher, Graetz, and Magnus in Germany, Bottomley and Tyndall in England, Violle, Garbe, Becquerel and Mouton in France, and Langley and Nichols in America. A part of these results were included in the communication to which reference has already been made.

In testing Stefan's formula* Schleiermacher measured the loss of energy sustained in unit of time by a platinum wire, heated to a given temperature within a good vacuum by means of the electric current and surrounded by an envelope kept at

* Wiedemann's Annalen, xxvi, p. 287.

a lower fixed temperature. The temperature of the wire was deduced from the variation in its resistance. The result was to show that for low temperatures Stefan's formula gives results that are too great, and for high temperatures they are too small. The application of Weber's formula to Schleiermacher's data yields results that are more consistent.

The following experiments have been made with a view to comparing the formulas of Dulong and Petit, Rosetti, Stefan and Weber in their application to temperatures but little removed from that of the atmosphere, not employing the indirect method of Schleiermacher, but measuring temperatures directly with the thermometer and radiation with the thermopile.

The radiating body was a metallic disk instead of the Leslie cube. A hole was drilled into it, parallel to one of its flat surfaces and extending nearly to the center. This was for the reception of a thermometer. The disk could therefore be raised to any desired temperature within the range of the thermometer, and its temperature be noted at any moment while it was cooling. One face was kept always scrupulously clean and smooth so as to prevent variations in emissive power. This face was turned toward a thermopile at a fixed distance from it. The thermopile was enclosed in a double-walled box of sheet brass for the purpose of preventing draughts and other disturbances that might affect its temperature. Through the cover of this box a delicate thermometer was passed, so that its bulb rested almost in contact with the thermopile. Variations of temperature within the box were thus measurable to within a hundredth of 1° C. In the end of the box turned toward the disk was a circular opening, 7^{cm} in diameter, provided with a double-walled adjustable brass cover. This was controlled by means of a string so that the thermopile could be exposed to radiation for a brief interval and then shut off from this. The thermopile was connected with a very delicate mirror galvanometer of low resistance, and all readings were taken by means of telescope and scale. The sensitiveness of this galvanometer was tested from time to time by putting it in circuit with a standard Clark cell and a resistance of 72,000 ohms. Around the suspended disk, except on the side toward the thermopile, double brass screens were placed, and a screen also above the space between it and the box. Disturbing air currents were thus avoided, not completely, but as far as possible. The entire apparatus was in a basement room whose temperature remained very nearly constant from day to day. A thermometer, hung outside of the brass screens, permitted comparison between the temperature of the room and that within the box containing the thermopile.

Before beginning any one series of observations, readings were taken from each of the three thermometers. These had of course been previously compared and found reliable, so that the correction for difference between them was very small. The disk had been hanging in position for some hours, but on exposure the thermopile always indicated a slight difference of temperature between itself and the disk, amounting to one or more scale divisions. This deflection was recorded, to be used as a correction to subsequent readings. The disk was then removed, heated up to a given temperature in excess of any to be measured, and hung again in position. After a few minutes its temperature was noted, the thermopile exposed long enough only to produce a throw of the galvanometer needle, the temperature of the disk immediately again noted, and also the temperature of the thermopile as indicated by the thermometer in the box. This procedure was repeated at intervals of two minutes during one or two hours, in which the disk became cooled down to a temperature differing but little from that of the room.

The arrangement of apparatus and the procedure just described was that finally adopted after many days had been spent and many hundreds of observations taken which had failed to yield satisfactory results. With the utmost care it is impossible to exclude air currents from the disk, and hence irregularities in its radiation. The same remark would apply equally to the Leslie cube, with the additional consideration that convection currents within the cube during its cooling would be very hard to control, even with assiduous stirring. At each exposure of the thermopile the air around it becomes warmed slightly by the disk, and it cannot be assumed that the temperature of the room is that of the thermopile after the first few exposures have been made. By enclosing the instrument in a box, this warm air, it is true, is prevented from passing away; but this disadvantage is much more than offset by the possibility of measuring and recording the increase of temperature, for which a curve of corrections is afterward made.

To continue any one series of observations until the difference of temperature between disk and thermopile vanishes is obviously impossible. Even when this difference amounts to several degrees disturbances are apt to produce such irregularities in the indications of the thermopile as to introduce serious error. By artificially cooling the disk until it seemed to indicate the same temperature as the box it was found that uncontrollable errors were introduced. It was best therefore to allow the cooling by radiation to continue until a temperature-difference of 5° or 10° remained, recording the corre-

sponding deflections at the usual intervals. To find out what would be the residual deflection, if this temperature-difference as indicated by the thermometers were reduced to zero, advantage is taken of the fact that for such small differences the curve expressing the radiation is approximately a straight line. Taking therefore the recorded small temperature-differences as abscissas and the corresponding deflections as ordinates, a straight line is drawn through the points thus found. Prolonging the line in a negative direction until it cuts the axis of ordinates, the distance of the point of intersection above or below the origin gives the correction to be applied to these final readings. The correction to the initial readings having been taken before heating the disk, and the slight variation of temperature in the box having been recorded, we have the means of constructing at least an approximate curve of corrections for all intermediate readings.

It is scarcely necessary to add that all thermometer readings were corrected for the difference of temperature between bulb and tube, and that all scale readings were reduced to those which would have applied to a circular arc.

The disk employed in the majority of the experiments was made of iron, though a number of measurements were made also with one of copper of the same dimensions. The distance from disk to thermopile was kept constant for each single series of observations, but this distance was varied from 30^{cm} to 40^{cm} according to necessity, and the sensibility of the galvanometer likewise varied, for different ranges of fall of temperature. The superior conductivity of copper ensures quicker equalization of temperature throughout the disk of this metal, but that of iron is amply sufficient, while its higher coefficient of emission makes the experiments less tedious and less subject to error than when a disk of copper is employed. The disk constitutes a short cylinder whose radius is $r = 7{\cdot}3^{cm}$ and whose length is $2\,l = 1{\cdot}4^{cm}$ or the distance from center to flat surface of the cylinder is $l = 0{\cdot}7^{cm}$. It can be shown* that if a thermometer bulb be placed within such a cylinder of heated iron at its center, and if it be assumed that a brief interval of time, such as one minute, has elapsed, then between the center of the disk and the nearest point on its face, at a distance of $0{\cdot}7^{cm}$ the absolute temperature does not vary more than 0·0002 of itself, or 0·02 of 1 per cent; also that the temperature-difference between center and circumference of the flat surface, an interval of $7{\cdot}3^{cm}$, does not exceed 0·18 of 1 per cent. It is safe to assume therefore that no error so great as the necessary errors of observation can be introduced by accepting the temperature

* Lectures of H. F. Weber on the Theory of Cylinder Functions and their application to the Problems of Physics.

indicated by the thermometer as the temperature of the radiating surface.

The method of work and the degree of accuracy attained may now be further illustrated by tabulating some of the results.

Tables I and II exhibit two independent series of measurements, on a fall of temperature through 40° C., the initial temperatures being approximately 60° C. as shown. For convenience the tables are arranged in the order of the intervals of time included in each, rather than in that of increasing temperature-difference which would on some accounts be preferable. The measurements were on the radiation of the iron disk. For the series indicated by Table I the initial deflection obtained before heating the disk was $\delta_1 = +0{\cdot}3$ scale division. The disk was then heated up to a temperature a little in excess of 60° and hung in position. While it cooled down to 21°·6 a series of 57 observations were made at intervals of two minutes. The residual correction was then found to be $\delta_2 = -2{\cdot}0$ scale divisions. The sensitiveness of the galvanometer remained unchanged during the 114 minutes of work, while the temperature within the box was raised from 16°·16 to 16°·72. For the purpose of tabulation the absolute temperatures, time intervals, and corresponding galvanometer deflections were obtained by interpolation for intervals of 5° in succession, after all necessary corrections had been applied to the recorded readings. The horizontal column H gives the hour and minute at which the record thus obtained should have been made. Column T gives the absolute temperatures of the disk, T_0 those of the thermopile, and $T - T_0$ the temperature differences. Column E gives the experimental result in radiation, as obtained in scale divisions of deflection. Column W gives the numbers for $\left(\frac{T}{T_0} e^{a(T-T_0)} - 1\right)$, which is the factor involving the variable, T, in Weber's formula. Column S gives the numbers for $\left(\frac{T^4}{T_0^4} - 1\right)$, involving the same variable in Stefan's formula. Each number thus obtained by formula is then divided by the corresponding values of E in the same vertical column obtained by experiment. The quotients are arranged in the horizontal columns W ÷ E and S ÷ E respectively, and multiplied by a power of 10 for the purpose of avoiding inconvenient decimals. This has no influence since our object is only that of comparison. If a formula be correct, and if the measurements be free from error, the numbers contained in the corresponding horizontal column of quotients should be identical. If they progressively increase or decrease

through the series, this shows that the formula gives results that are progressively too high or too low, as the case may be.

The explanation just given applies equally to Tables II, III and IV, the last two of which represent a fall of temperature through 80°.

TABLE I.

H	$9^h\ 29^m$	$9^h\ 33^m$	$9^h\ 39^m$	$9^h\ 45^m$	$9^h\ 53^m$	$10^h\ 3^m$	$10^h\ 19^m$	$10^h\ 38^m$	$11^h\ 18^m$
T	334·16	329·20	324 26	319·33	314·43	309·52	304·61	299·65	294·72
T_0	289·16	289 20	289·26	289·33	289·43	289·52	289·61	289 65	289·72
$T-T_0$	45	40	35	30	25	20	15	10	5
E	419·1	366·9	315·4	264·6	218·6	171·0	126·6	83·8	41·3
W	0·403	0·352	0·302	0·255	0·210	0·165	0·122	0·080	0·040
S	0·783	0·680	0·578	0·485	0·392	0·306	0·225	0·145	0·069
W÷E	962	959	957	964	960	965	964	966	968
S÷E	187	185	183	183	179	179	178	175	167

TABLE II.

H	$9^h\ 47^m$	$9^h\ 53^m$	$9^h\ 58^m$	$10^h\ 5^m$	$10^h\ 13^m$	$10^h\ 24^m$	$10^h\ 38^m$	$10^h\ 59^m$	$11^h\ 37^m$
T	332·98	328·08	323·18	318 32	313·46	308·63	303·82	299·00	294·13
T_0	287·98	288·08	288·18	288·32	288·46	288·63	288·82	289·00	289·13
$T-T_0$	45	40	35	30	25	20	15	10	5
E	426·1	374·4	321·4	271·0	221·9	173·7	127·3	84·7	42·0
W	0·403	0·352	0·302	0·255	0·210	0·155	0·122	0·080	0·040
S	0·783	0·680	0·578	0·485	0·392	0·306	0·225	0·145	0·069
W÷E	946	940	940	941	946	950	958	945	952
S÷E	184	182	180	179	177	176	177	171	164

TABLE III.

H	$10^h\ 16^m$	$10^h\ 20^m$	$10^h\ 25^m$	$10^h\ 30^m$	$10^h\ 36^m$	$10^h\ 44^m$	$10^h\ 54^m$	$11^h\ 9^m$	$11^h\ 32^m$
T	384·21	374·25	364·33	354·40	344·49	334·57	324·65	314·70	304·70
T_0	289·21	289·25	289·33	289·40	289·49	289·57	289·65	289·70	289·70
$T-T_0$	95	85	75	65	55	45	35	25	15
E	347·6	302·7	256·3	214·2	175·0	138·7	103 9	72·2	42·0
W	0·999	0·865	0·739	0·619	0·508	0·403	0·302	0·210	0·122
S	2·113	1·803	1·574	1·249	1·006	0 780	0·578	0·392	0·225
W÷E	287	286	288	289	290	290	291	291	290
S÷E	608	596	591	583	575	562	556	543	536

TABLE IV.

H	$10^h\ 35^m$	$10^h\ 39^m$	$10^h\ 43^m$	$10^h\ 45^m$	$10^h\ 54^m$	$11^h\ 2^m$	$11^h\ 12^m$	$11^h\ 27^m$	$11^h\ 49^m$
T	385·27	375·30	365·35	355·43	345·50	335·61	325 68	315·71	305·81
T_0	290·27	290·30	290·35	290·43	290 50	290·61	290·68	290·71	290·81
$T-T_0$	95	85	75	65	55	45	35	25	15
E	432·0	376·0	320·0	266·2	218·2	173·0	129·5	89·8	52·6
W	0·999	0·865	0·739	0·619	0·508	0·403	0·302	0·210	0·122
S	2 113	1·803	1·514	1·249	1·006	0·780	0·578	0·392	0·225
W÷E	231	230	231	233	233	233	233	234	232
S÷E	489	480	473	469	461	451	446	437	428

If now each one of the series of numbers in column W ÷ E or S ÷ E be divided by the mean of the series the successive quotients will differ but little from unity. The corresponding horizontal column of results we may call the column of deviations. If the numbers in this column be represented by a curve, with temperature-differences for abscissas, this curve should be

very nearly a straight line parallel to the axis of abscissas. It will be most convenient to arrange such a series therefore in the order of increasing temperature-differences, which is the reverse of that in the tables just given. Any irregularities in the curve must be due to the errors of experiment, and partly to the fact that logarithmic results are only approximations. Table V is made up of the deviation columns from five independent series of observations ranging through 40°, to which Weber's formula has been applied. Table VI contains the application of Stefan's formula to the same series.

Table VII shows Weber's formula, and Table VIII Stefan's formula, applied to six independent series of observations ranging through 80°. In each case the mean of each vertical column is shown.

TABLE V.—*Weber.*

$T-T_0$	5	10	15	20	25	30	35	40	45
I	0·983	0·989	1·005	1·007	1·007	0·997	1·001	1·007	1·007
II	1·008	0·998	1·013	1·004	1·000	0·993	0·992	0·993	0·999
III	1·006	1·002	0·998	1·003	0·998	1·001	0·995	0·997	0·999
IV	....	1·001	1·006	1·006	1 006	0·994	0·993	1·002	0·994
V	....	1·002	1·009	1·011	0·996	0·996	0·996	0 996	0·997
Mean	0·999	0·998	1·006	1·006	1·002	0·996	0·995	0 999	0·999

TABLE VI.—*Stefan.*

$T-T_0$	5	10	15	20	25	30	35	40	45
I	0·906	0·971	0·991	0·998	1·008	1·012	1·027	1·040	1·046
II	0·928	0·980	0·998	0·995	1·000	1·008	1·017	1·025	1·045
III	0·928	0·987	0·988	0·995	0·999	1·016	1·021	1·007	1·039
IV	---	0·973	0 983	0 989	0·997	1·000	1·009	1·043	1·024
V	....	0 977	0·986	0·993	0·988	1·002	1·012	1·020	1·026
Mean	0·921	0·978	0·989	0·994	0 998	1·008	1 017	1·023	1·036

TABLE VII.—*Weber.*

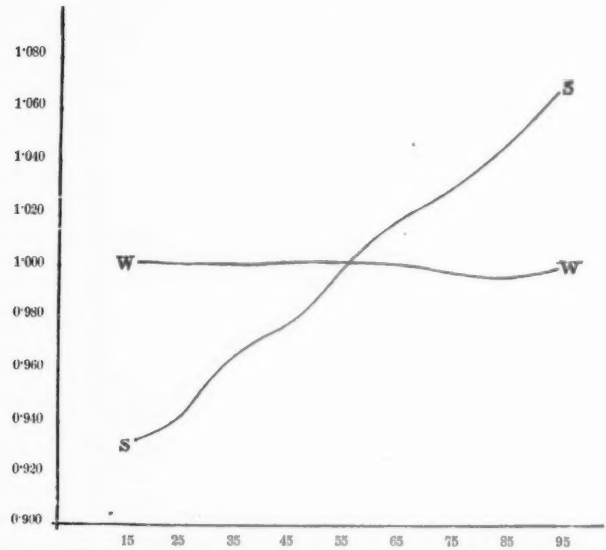
$T-T_0$	15	25	35	45	55	65	75	85	95
I	0·993	0 977	0·997	1·001	1·014	1·024	0·992	1·006	0·996
II	1·004	1·006	1·005	1·004	1·003	0·999	0·996	0 988	0·996
III	1·014	1·009	1·003	1·002	0·999	0·993	0·990	0·993	0·995
IV	0·997	1·011	1·002	1·002	0·997	0·990	1·014	1·001	1·017
V	0·999	1·001	1·004	1·003	1·002	1·001	0·995	0·991	0·996
VI	....	....	1·000	1·001	1·001	1·001	0·999	0·998	....
Mean	1·001	1·001	1·001	1·002	1·002	1·001	0·998	0 996	1·000

TABLE VIII.—*Stefan.*

$T-T_0$	15	25	35	45	55	65	75	85	95
I	0·925	0 922	0·965	0·979	1·014	1 044	1·027	1·059	1 064
II	0·937	0·949	0·973	0·983	1 005	1·019	1·032	1·041	1·063
III	0·945	0·953	0·971	0·981	1·000	1·014	1·026	1·047	1·064
IV	0·926	0·951	0·966	0·977	0·995	1·006	1·046	1·051	1·083
V	0·931	0·950	0 972	0·982	1·003	1·021	1·030	1·042	1·065
VI	....	....	0·957	0·970	0 993	1·024	1·024	1·042	....
Mean	0·933	0·945	0·968	0·979	1·002	1·019	1·031	1·047	1·068

The mean results of Tables VII and VIII are expressed graphically in the curves of fig. 1. Here it is seen that Weber's formula is expressed by a curve (WW) nearly parallel to the axis of abscissas, but with slight irregularities, as might be expected in any representation of experimental results. At no point is the deviation so great as 0·5 of 1 per cent. Stefan's formula is expressed by a curve (SS) which is plainly oblique to the axis of abscissas, the greatest deviation being more than 6 per cent. These experiments therefore confirm the result otherwise attained by Schleiermacher, indicating that for temperatures but little above that of the atmosphere Stefan's formula gives a rate of increase of radiation that is too rapid, while Weber's formula coincides very closely with the results yielded by experiment.

Fig. 1.

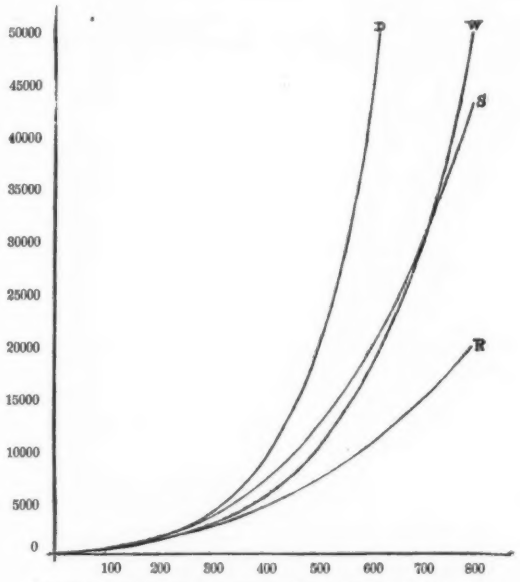


Curves of deviation for formulas of radiation for temperatures from 30° to 110° C.

It may be of some interest in this connection to exhibit the application of these formulas to a wider range of temperature difference. For this purpose the constants of each formula have been determined from the data contained in the tables just given; those of Rosetti's formula being obtained by method of least squares. In fig. 2, the abscissas represent temperature differences from 0° to 800° C., the temperature of the thermopile being taken as 17° C., which was the mean temperature of

the room in which the measurements were made. The ordinates are to be read in units of deflection on a scale such as was employed in the galvanometer readings representing radiant energy. For temperature-differences less than 100° these curves are nearly coincident. For high temperatures Stefan's formula gives results that are higher than those of Weber's formula; but the rate of increase by Weber's formula grows more rapidly, and for a temperature difference of about 720°, about that of red heat, the two curves cross each other,

Fig. 2.



Curves of radiation for temperatures from 17° to 817° C.

D. Curve for formula of Dulong and Petit.
W. " " " " Weber.
S. " " " " Stefan.
R. " " " " Rosetti.

and, from this point on, the indications of Stefan's formula become lower than those of Weber's formula. In this connection we may again refer to the experiments of Schleiermacher, who, by estimating change of temperature through variation of electrical resistance, found the indications of Stefan's formula to be less than the results obtained by experiment. The curve of Rosetti's formula gives a rate of increase in radiation that is about as much too low as that of Dulong and Petit is too high.

Art. LVI.—*Notes on Silver;* by M. Carey Lea.

Action of Ammonia.—Aqueous ammonia is supposed to be without action on normal silver but this is not so: under favorable conditions, silver is gradually taken up by this solvent.

The first experiments were made with silver reduced from the nitrate by the action of sodium hydroxide and milk sugar. The silver was very carefully purified from any possible trace of oxide. Placed in contact with ammonia for a few hours, silver was taken up. Its presence could be recognized either by ammonium sulphide or by adding a drop or two of hydrochloric acid and then supersaturating with dilute sulphuric acid; a dense cloud of silver chloride forms and this result can be obtained any number of times in succession by acting with ammonia on the same portion of silver.

A similar reaction was obtained with silver reduced from chloride by cadmium and hydrochloric acid removing afterwards all traces of cadmium. Silver reduced in this way is liable to contain traces of chloride. These were removed by covering the silver with strong ammonia, letting it stand over night and thoroughly washing out. This was repeated five times. From this silver, ammonia by twenty-four hours contact always took up enough to give a dense white cloud when treated as above.

Portions of solutions obtained in the last mentioned manner were evaporated to dryness over the water bath and left brownish black films. These were non-explosive and therefore did not consist of silveramine: they yielded a large proportion of silver to acetic acid, leaving behind a little metallic silver. The ammonia therefore, does not dissolve the silver as metal but as oxide. The presence of a little metallic silver in the residue left by evaporation was probably due to slight traces of oxidable organic matter contained in the ammonia. This opinion was confirmed by the fact that the solution when heated acquired a transparent red color.

It appears therefore that in the presence of ammonia, silver has a tendency to oxidize, for when the silver was placed in a vial with an air-tight fitting stopper, filling it about half full, and was then completely filled with liquid ammonia and tightly closed, it was found that in twenty-four hours a mere trace of silver was taken up. On the other hand when the silver was placed in a flat basin and merely moistened with ammonia more silver was taken up in five minutes than in the preceding case in twenty four hours.

This action of ammonia in promoting oxidation recalls its behavior with cobaltous salts and with copper. It is probably

the only case in which silver is oxidized (at ordinary temperatures) by atmospheric oxygen.

Action of Dilute Sulphuric Acid.—It is generally held that silver is insoluble in cold dilute sulphuric acid. Almost any form of silver, providing it is finely divided, is slightly soluble in sulphuric acid diluted with four or five times its bulk of water. With more dilute acid different varieties of silver act very differently. The most easily attacked is that which is obtained by reducing the oxide with alkaline hydroxide and milk sugar; from this a distinct trace is dissolved by sulphuric acid diluted with 100 times its bulk of water. From silver reduced from the chloride by cadmium this very dilute acid takes up nothing.

Nitric acid, sp. gr. 1·40, diluted to ten volumes and allowed to stand for an hour with finely divided silver, took up an extremely faint trace.

Hydrochloric acid, sp. gr. 1·20, was totally without action. The silver after being well boiled with water to remove every trace of acid, dissolves completely in nitric acid.

Acetic acid has no action upon metallic silver.

Various Reactions of Normal Silver.

Normal metallic silver even in a state of very fine division does not abstract the slightest trace of nitric acid from perfectly neutral cupric nitrate obtained by acting on pure cupric sulphate with barium nitrate. After fifteen hours of contact not a trace of silver had been dissolved.

But silver easily reduces cupric chloride with formation of purple photochloride. If the copper salt is present in slight excess the silver is so thoroughly acted upon that nitric acid does not extract a trace of it from the purple photochloride.

Metallic mercury instantly reduces silver nitrate but metallic silver takes chlorine from corrosive sublimate. The precipitate contains calomel and blackens with ammonia.

Silver in fine division slowly reduces a neutral solution of potassium permanganate.

Silver nitrate, as is well known, is reduced by ferrous sulphate, or ammonia ferrous sulphate, the iron at the same time becoming peroxidized and the silver assuming the gray metallic form. On the other hand silver powder rapidly reduces a neutral solution of ferric sulphate. A solution of iron alum readily dissolves metallic silver without the aid of heat;* in a few seconds the solution strikes a blue color with potassium

* The statement in the new Encyclopédie Chimique that heat is required and that the metal separates again on cooling (Tome iii, cahier 15, p. 248) appears to be incorrect.

ferricyanide and if the iron alum is in excess the whole of the silver is dissolved. It has been before noticed that the reactions between silver salts on the one hand and iron salts on the other are to some extent reversible, the observations just described place the matter in a somewhat clearer light. With a view of ascertaining whether ferrous sulphate could be completely oxidized by argentic oxide a portion of the ferrous solution was treated with successive portions of the oxide until the latter was no longer affected by it. But when this stage was reached the solution no longer contained a trace of iron, the whole of it had entered into combination with the silver. This combination is perfectly black and may probably have consisted of the compound described by H. Rose, as Ag_4O, $2FeO\ Fe_2O_3$ and obtained in the same way.

When ammonia iron alum is placed in contact with finely divided silver in considerable excess in a tightly closed vial the solution after a few days standing with frequent shaking acquires a deep red color. This may last for a week or more. The solution then decolorizes and becomes greenish but still contains abundance of ferric salt. Thus it appears that although silver has a powerful reducing action on ferric salts the action is self-limited and ceases long before complete reduction is effected for after many weeks contact in a closed vial there are abundant indications of the presence of ferric salt, although silver has been present in large excess.

ART. LVII.—*Notes on Silver Chlorides;* by M. CAREY LEA.

EXPERIMENTS made by J. J. Acworth* at the suggestion of E. Wiedeman showed that by heating silver chloride to a temperature of 220° C. it passes into a modification that was insensitive to light.

I think this change may be due to the complete driving off of moisture. Abney showed by a well-known experiment that silver chloride when exposed perfectly dry in vacuo in a glass tube was totally unaffected by light, but I have shown that fused silver chloride poured into petroleum and placed in the sun-light without removing it from the liquid, was instantly darkened.

These three experiments taken together lead to the following conclusions:

1. Silver chloride dry and perfectly isolated is insensitive to light. (Abney's experiment.)

* Wied. Referate, 1890, p. 518.

2. The presence of atmospheric air does not restore the sensitiveness, if the silver chloride has been absolutely dehydrated at 220° C. (Acworth's experiment.)

3. The presence of oxygen is not necessary or important for the darkening of silver chloride. The presence of moisture is not essential; its place may be taken by another substance capable of taking up chlorine. This follows from my experiment above mentioned.

There is no doubt that silver chloride retains the last portion of water with great obstinacy. I have frequently tried to dry silver chloride in hot air so that it should lose nothing further by fusion, but never quite succeeded. There is always a loss which may be roughly taken at a half a milligram and from thence upwards to nearly one milligram, in a gram. When the water is thoroughly driven off it is probable that the silver chloride is left in an insensitive condition. Acworth's experiments seem to show this.

So long as moisture is present the molecule of silver chloride easily breaks up, not merely by the action of light but by the application of any form of energy. The part played by moisture in chlorine reactions is somewhat remarkable. It has been lately stated that absolutely dry chlorine has no action upon copper foil. As soon as a trace of moisture is introduced, energetic action sets in.

ART. LVIII.—*A remarkable Fauna at the Base of the Burlington Limestone in Northeastern Missouri;** by CHARLES ROLLIN KEYES.

IN the description of a certain gasteropod (*Porcellia nodosa* Hall), in the third volume of the Illinois Geological Survey† occurs the following paragraph, in connection with the assigned horizon and locality: "Lower Carboniferous; Barry, Pike county, Illinois; from a peculiar cherty, calcareous band at the base of the Burlington limestone, formerly supposed to belong to that rock, but now known to contain fossils characterizing the oolitic upper bed of the Kinderhook group, at Burlington, Iowa."

This allusion though merely incidental is the only direct one ever known to be made to the particular beds now under consideration.

* Published by permission of Mr. Arthur Winslow, Director of the Geological Survey of Missouri. from work prosecuted during the years 1891–92.

† Geol. Surv. Illinois, vol. iii, p. 459. (1868).

At Louisiana, in Pike County, Missouri, which is separated from Pike County, Illinois, only by the Mississippi River, the "white chert" beds are much better developed than any where else in the region. It is from the Missouri locality that the recent collections have been made. Here the Burlington limestone is well exposed in the hilltops, where extensive quarries have been opened.

For more than 70 miles, from above Quincy to below Louisiana, the Burlington limestone forms an almost continuous mural escarpment capping the high bluffs on either side of the Mississippi River. These bluffs rise to a height of from 300 to 400 feet above the water level. In many places they form bold, overhanging cliffs, with a heavy talus at the base.

A vertical section of the rocks at Louisiana is as follows:

	Feet.
16. Brown and white, compact, encrinital limestone, thinly bedded, with some chert	75
15. White, encrinital limestone, very heavily bedded,	12
14. Coarse-grained, encrinital limestone, with irregular chert bands	20
13. Very heavily bedded, white encrinital limestone, with a peculiar white chert in nodules and irregular bands	11
12. Brown, encrinital limestone, compact and heavily bedded, somewhat earthy in places	15
11. Compact, fine-grained, buff limestone, with few or no partings	15
10. Sandy shales, brownish, forming soft, friable sandstone locally	12
9. Greenish, clayey shales	70
8. Thin-bedded, compact limestone, fine-grained, with conchoidal fracture, in layers 4 to 6 inches in thickness, like lithographic stone in texture and appearance	50
7. Sandy clay-shale	3 inches.
6. Drab or greenish clayey shale	2
5. Black, fissile clay-shale	4
4. Buff, magnesian limestone, very heavily bedded	10
3. Compact, white oolite	5
2. Blue clay-shale, with thin bands of impure limestone rich in fossils	60
1. Heavily bedded limestone, exposed	5

Number 1 is the Trenton limestone; 2 the Hudson River shales. 3 and 4 probably represent the Niagara limestone; the first increasing rapidly in thickness southward and in a distance of 20 miles reaches a vertical measurement of 30 to 40

feet. 5 and 6 are probably Devonian, equivalent to the "black shale" of adjoining States. Number 7 is a thin seam 2 to 4 inches in thickness and highly fossiliferous. With few exceptions the "Lithographic" fossils come from this layer. It probably belongs more properly with beds 5 to 6. Apparently the organic remains are nearly all identical with forms from the Hamilton rocks farther northward. Should the union of this thin, highly fossiliferous seam to the underlying shales be more in harmony with the real relation of the faunas of the respective beds, as now seems likely, than with the faunas above, it would remove to a great extent the present Devonian facies from the Lithographic (Louisiana) limestone. 8 is the Louisiana limestone, a compact rather thinly bedded rock, breaking with a conchoidal fracture. It is very poor in fossils. Numbers 9 and 10 are the Hannibal shales. 11, the Chouteau limestone, with a few fossils. Number 12 is the Burlington limestone with the characteristic basal fauna of the Burlington. 13 is also the lower Burlington, carrying considerable chert and containing the most prolific fauna in the section. 14, 15 and 16 belong to the Burlington limestone; the upper portion containing the typical fauna distinctive of the upper division.

From Quincy southward the strata rise very gradually, until the Burlington limestone, which appears a few yards above the water level at that place, has an elevation of more than 250 feet above the river, at Louisiana. Below the limestone as will be seen from reference to the section, the beds are principally soft shales, which are eroded much faster than the great thickness of heavy, compact lime-rock overlying. High hills with precipitous slopes are formed. These are capped by the more indurated layers, rising in almost vertical walls from about midway up the elevations. In consequence of this, a peculiar and very striking phase of topography is produced, reminding one very forcibly of the topographical effects in a great driftless area of northeastern Iowa and the adjoining States.

North of Quincy, as already stated, the Burlington rock dips below the water level of the Mississippi and does not appear again until just above Ft. Madison, in Iowa, while at the city of Burlington the base of the limestone is nearly 100 feet above low water-mark. At this place the organic remains have received more attention than anywhere else, while the vertical ranges of the different species have been determined with great accuracy. From this locality, also, the extensive faunas of the Kinderhook were first made known, and many species described.

A third of a century has passed since the investigations of Hall, White, and Winchell brought to light so many interest-

ing forms which characterize the beds immediately below the Burlington limestone. At Burlington, too, the Kinderhook and Burlington formations are sharply contrasted lithologically; while faunally the two horizons are equally well defined.

Passing southward one hundred miles, to Louisiana, Missouri, the same lithological and faunal features are found as at Burlington. These characters are shown for 50 miles along the great river in this vicinity.

In the lower bed of the Burlington limestone (Number 12 of the section) is found the typical and well marked basal fauna of this formation. Many of the species, however, have a somewhat greater vertical range than at the Iowa localities.

Among the most characteristic species of Crinoids to be mentioned are:

Orophocrinus stelliformis (Owen & Shumard).
Cryptoblastus melo (Owen & Shumard).
Granatocrinus projectus (Meek & Worthen).
Rhodocrinus Wachsmuthi Hall.
Rhodocrinus Wortheni Hall.
Agaricocrinus brevis (Hall).
Dorycrinus unicornis (Owen & Shumard).
Dorycrinus subaculeatus (Hall).
Batocrinus aequalis Hall).
Batocrinus longirostris (Hall).
Batocrinus elegans (Hall).
Actinocrinus proboscidialis Hall.
Actinocrinus tenuisculptus McChesney.
Physetocrinus ornatus (Hall).
Steganocrinus sculptus (Hall).
Steganocrinus araneolus Meek & Worthen.
Platycrinus Americanus Owen & Shumard.
Platycrinus Burlingtonensis Owen & Shumard.
Platycrinus discoideus Owen & Shumard.
Platycrinus subspinosus Hall.

The fauna of this bed (about 15 feet in thickness) is primarily a crinoidal one. The above mentioned forms are some of the most important marking the limited horizon. Many other crinoids as well as brachiopods, corals, gasteropods, etc., are mingled; but they range upward into other layers more or less extensively.

Above the basal bed is a slightly thicker member, of an intensely white color (number 13 of the section). It is chiefly encrinital like the other, but in addition contains a larger amount of comminuted shell material derived from molluscan remains. In places the shell fragments predominate, forming a fine shell breccia not unlike the well known coquina rock of Florida; but it is, however, so compact that good specimens

of fossils are almost impossible to dislodge. The layers of this bed contain also considerable amounts of chert in small nodules and nodular bands. When first exposed in quarrying these cherts are very compact, translucent, and breaking with a conchoidal fracture. Upon exposure to the weather these flints quickly slacken like quick-lime to a fine intensely white powder. If examined before the process of disintegration has proceded more than half way the white nodules are found to be charged with fossils, which when taken out cannot be told from plaster-of-paris casts. Before affected by the atmospheric agencies, few or no traces of organic remains can be detected in the cherts. But they actually contain a very extensive assemblage of fossils; and in a perfect state of preservation when collected at the right time. They afford unusual opportunities for both structural and systematic studies; for many of the features commonly not met with are here found beautifully preserved; such as the internal characters of crinoids and brachiopods, and the delicate ornamentation in nearly all groups.

Upon careful comparison of the fossils in the cherts and in the surrounding limestones, so far as is possible in the latter, the fossils are found to be identical to a great extent. Moreover, numerous shells and crinoids are found partly embedded in the chert and partly in the limestone, with a sharp line of separation, showing clearly that the siliceous impregnation had been acquired long after the original deposition of the beds, and was not due to a greater silicity of waters in which the calcareous deposits were made. This is in accordance with observations made elsewhere in the Burlington limestone of other localities.

The faunal aspects of the bed in question (number 13 of the section) are particularly interesting. Some of the more common as well as more important species are enumerated below;

Lingula melie Hall.
Discina Newberryi Hall.
Terebratula Rowleyi Worthen.
Productus arcuatus Hall.
Productus lævicostus White.
Productella Shumardiana (Hall).
Rhynchonella Missouriensis Shumard.
Spirifera peculiaris Shumard.
Strophomena rhomboidalis var.
Allorisma Hannibalensis Shumard.
Edmondia nuptialis Winchell.
Edmondia Burlingtonensis White & Whitfield.
Conochardium sp.?
Lithophagus occidentalis (White & Whitfield.)
Aviculopecten circulus Shumard.

Phanerotinus paradoxus Winchell.
Capulus paralius (White & Whitfield).
Capulus formosus (Keyes).
Porcellia nodosus Hall.
Loxonema prolixa White & Whitfield.
Loxonema sp.?
Spherodoma penguis (Winchell).
Pleurotomaria sp.?
Holopea subconica Winchell.
Murchisonia sp.?
Bellerophon bilabiatus White & Whitfield.
Straparollus ammon (White & Whitfield).
Straparollus luxus? (White).
Omphalotrochus Springvallensis (White).

The forms in the accompanying list are all species which characterize the Kinderhook of Burlington, Iowa; most of them being originally described from that place. In addition many more species of lamellibranchs, brachiopods and gasteropods occurring very abundantly at the latter locality are found in the white chert of Louisiana along with a few of the Burlington limestone species.

It is to be noted that:

(1) The fauna of this horizon is predominantly molluscan, representing a marked contrast with that of the typical Burlington limestone, which is prevailingly crinoidal, with some brachiopodal forms.

(2) The fauna is the typical one of the Kinderhook beds.

(3) There is mingled with this fauna some of the forms from both above and below, which are thus associated with the species representing the typical lower Burlington limestone.

Here, then, is a well defined Kinderhook fauna intercalated in the Burlington limestone, with practically no change of lithological characters; a lower fauna suddenly appearing in the midst of a higher. This is the most marked instance of the kind that is at present known in the Carboniferous of the Mississippi Valley. Though the time separation is not very great, the present case is a striking illustration of Barrande's celebrated "doctrine of colonies," so clearly developed in the Système Silurien du Centre de la Bohème,* and so ably defended in his "Défense des Colonies."

It is not to be inferred, however, that during the short supremacy of the lower fauna in midst of an upper there was a complete extinction of the deposed forms; but rather that owing to peculiar conditions the lower fauna merely displaced the upper temporarily; or pushed it aside into other districts for the time being.

* Vol. i, p. 73, (1852.)

ART. LIX.—*Glacial Pot-holes in California;* by H. W. TURNER, of the United States Geological Survey.

IN the cañon of the North Fork of the Mokelumne River, California, about thirty miles a little west of south from Lake Tahoe, and at an elevation above sea level of about 4,500 feet, is a group of pot-holes in the granite. The cañon here was formerly the bed of a glacier, as is evidenced by the polish and grooving of the rock and the perched bowlders. The rock about is quite devoid of soil. The pot-holes are from two to four feet in diameter and some of them are four feet deep. The shape of some of them is nearly conical, others more nearly cylindrical. Most of the pot-holes are eroded vertically, but some of them are inclined. A number are quite shallow, but even these are broad and saucer-shaped. The granite flakes off in shells nearly parallel to its surface, and this would account for the broad form of the pot-holes at the commencement of their formation.

The pot-holes are about 250 in number and from six inches to six feet apart. They seldom or never coalesce and the regularity of their arrangement is noticeable. The interior of all of the holes is well rounded and smooth, as pot-holes usually are. In some of them are rounded fragments of rocks; others are filled with sand and gravel. They cover a gently inclined surface of about two thousand square feet. To the north is a glaciated bank of granite, and the pot-holes occupy about the position that would be expected if formed by water falling over this bank. The height of the bank above the pot-holes is approximately forty feet. One pot-hole exists in the side of this bank several feet above its base.

The river at the present time runs at a level of perhaps twenty or thirty feet below the lowest pot-holes. The place is locally known as Ham's Salt Springs. Salt water oozes out from crevices in the rock and collects in several of the lower pot-holes. By evaporation, salt (NaCl) crystallizes out so that the water is usually covered with a thick layer of very pretty hopper-shaped crystals.

The Indians are said to have formerly congregated here, attracted no doubt by the salt springs. Numerous small arrow-heads, chiefly of jasper and obsidian, were found by my party a little west of the pot-holes. At a point on the bare granite below the pot-holes and very near the river are several small mortar holes such as are used by the Indians to grind up acorns, and which are frequently found in bare rocks in the Sierra Nevada.

At the time of my visit an old white man named Carlton was camped there with some Indians. He has been living with the Indians in the neighborhood of the Mokelumne River since 1851. He states that these pot-holes were made by the Indians for the purpose of collecting the salt water, in order to allow the salt to crystallize from it. On questioning him I could not make out that he himself had known of any such holes being excavated by the Indians. It would not, however, be a very difficult matter for the Indians to have made them. If a fire is built on the granite it flakes off very readily, and by repeating this operation for some time and using utensils in addition, cavities could be made. Mr. W. Q. Mason, of Volcano, California, who guided my party to the spot, believes the pot-holes to be the work of Indians.

Plate IX represents a partial view of the pot-holes above described. The salt water at present oozes out at a point which may be located in the plate as about one-half inch from the middle of the left-hand side. It therefore runs only into some of the lower holes not represented in the picture.

On a granite spur just south of the pot-holes and perhaps 100 feet vertically above them is a little lake, partially filled with flags and tules. It has no outlet, but when the water is high it can readily escape at its west end. The water is brackish. Some salt water must therefore have a higher source than that above indicated; and it is possible that salt water formerly flowed from crevices at points above the pot-holes and may have filled more of them than it does at present.

The fact that few or none of the pot-holes coalesce perhaps favors the theory that they were made by the Indians, since in nature, pot-holes near one another frequently coalesce. The pot-hole, above described, in the side of the granite bank is evidently the work of falling water. It seems most likely that all the pot-holes were formed by the action of water, probably in some way connected with the glacier that formerly filled the cañon.

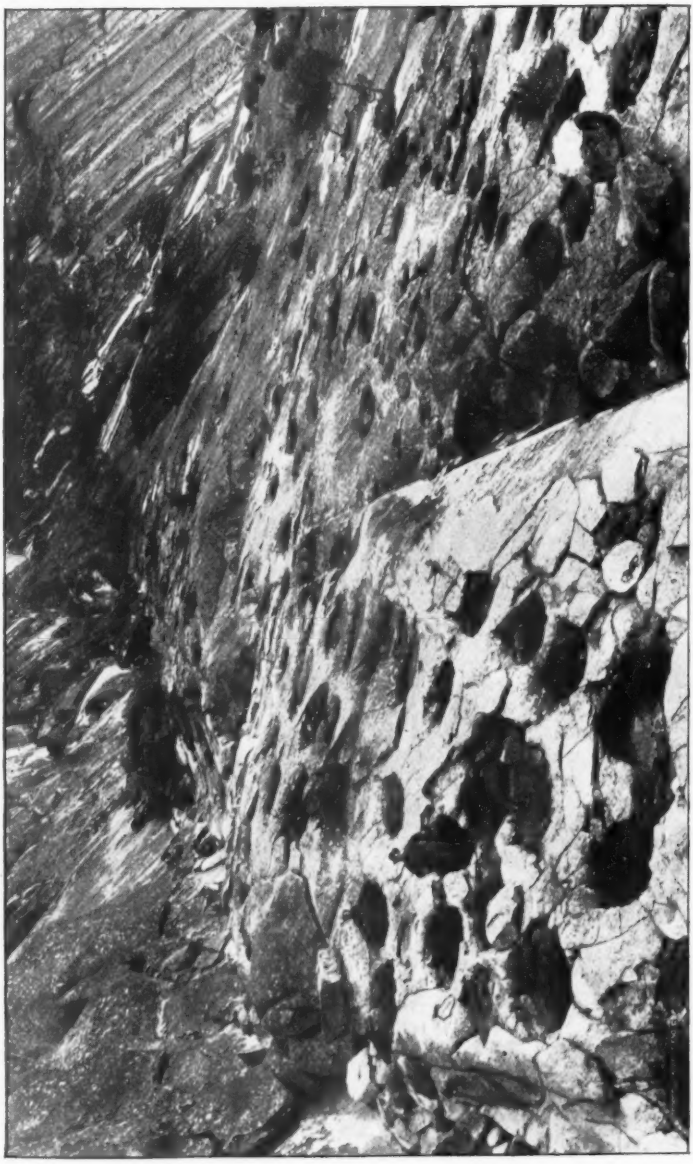
In this connection the reader is referred to an article by T. T. Bouvé* who describes some glacial pot-holes near Cohasset, Mass., and to Brögger and Reusch† who have studied those of Norway where pot-holes are numerous.

It is interesting to note that in Norway they were at one time considered the work of the giants supposed once to inhabit that region, and that in America they are ascribed to the aboriginal Indians.

Washington, D. C., September 5, 1892.

* Indian pot-holes or giants' kettles of foreign writers, Proc. Boston Soc. Nat. Hist., vol. xxiv. pp. 218–226.

† Giants' kettles at Christiana, Quart. Jour. Geol. Soc., vol. xxx, pp. 750–771.



Pot-holes in Mokelumne River Cañon, California.

Art. LX.—*The Lavas of Mount Ingalls, California;* by H. W. Turner, Washington, D. C.

[By permission of the Director of the U. S. Geological Survey.]

Mount Ingalls is situated just south of the fortieth parallel in Plumas county, California. It forms a portion of the eastern crest of the Sierra Nevada. Its elevation is 8,484 feet above sea level, according to the determinations of the topographers of the U. S Geological Survey.

Mount Ingalls was a center of volcanic activity during much of later Tertiary time. The lavas which originated in its vicinity form an interesting series. The following rocks are represented:

I. *Late basalt*, a rather coarse gray rock with much pyroxene and some olivine. It is usually massive.

II. *Andesite*, containing both pyroxene and hornblende, and occurring chiefly as a breccia.

III. *Older basalt*, a dense black rock with little olivine, and a good deal of magnetite. It seems always massive.

IV. *Rhyolite*, in very small amount.

The order of succession is that indicated by the Roman numerals with the exception of rhyolite (IV.) As has been previously noted* the rhyolite of the Sierra Nevada underlies the andesites, but its relation to the older basalt (III) is undetermined. The rocks may be roughly characterized as follows:

I. *Late basalt.*—This is macroscopically a coarse to medium grained light gray rock, sometimes pinkish, with large scattered olivines. Under the microscope it is seen to be nearly holocrystalline and to be composed of lath-like plagioclase, augite and magnetite, with occasional large olivines. One of the slides shows a hypocrystalline glassy base containing abundant grains of magnetite, with numerous phenocrysts of plagioclase and augite, and a few hypersthenes and olivines. In general, however, very little glass is to be seen.

The late basalt is the most recent of the lavas of this portion of the Sierra Nevada. It forms the summit and nearly all of the sides of Mount Ingalls down to and in places below the 7,000 foot contour. It rests, to a large extent, on andesitic breccia. Similar basalt caps a number of the higher points to the south and southwest of Mount Ingalls. Two of these are Mount Jackson and Penman Peak. There also the basalt rests on andesite. The later basalt is almost everywhere a massive

*Mohawk Lake Beds, Bull. Wash. Phil. Soc., vol. xi, p. 389.

rock, but a small amount of basalt-breccia and scoriaceous basalt forms two points on the summit of Mount Ingalls, perhaps remains of a former crater. In the ravine that heads just east of the summit of Mount Ingalls the basalt is glaciated. Its age, therefore, antedates that of the glaciers of the Sierra Nevada.

II. *Andesite.*—This is chiefly a breccia. The angular fragments of andesite from this breccia are usually coarsely crystalline and frequently vesicular. The color is dark gray, the feldspars showing as white spots. Frequently hornblende needles are macroscopically visible.

Under the microscope the andesite is composed of phenocrysts of plagioclase and pyroxene and of occasional hornblendes in a groundmass sometimes very glassy, sometimes hypocrystalline with abundant plagioclase microlites and usually considerable magnetite. The pyroxene in some cases is largely augite; but there is frequently a good deal of hypersthene. Sometimes the rock is nearly holocrystalline. In some dark compact specimens of the andesite hypersthene is the most abundant bisilicate, but the prevailing type is the coarser one above described, and usually the predominant bisilicates are augite and hornblende.

Andesitic breccia forms most of the ridge that extends southeasterly from Mount Ingalls. The same area continues to the north of Red Clover Valley.

III. *Older basalt.*—This is a dense black rock usually showing macroscopically no porphyritic constituents except occasional olivines. It is frequently roughly columnar, the prisms being small, seldom more than three or four inches in diameter. The rock has been nowhere seen by the writer except in the massive form.

Microscopically the rock is composed of lath-like plagioclase with more or less olivine and some augite in a groundmass which is rendered dark by the abundant magnetite. The groundmass sometimes contains considerable glass and frequently specks and minute prisms of augite. Much of the olivine is altered to serpentine. The plagioclases are usually small and of nearly even size. One slide, however, shows porphyritic plagioclases and olivines in a groundmass of plagioclase microlites, magnetite and glass.

The older basalt forms an area of several square miles to the east of Mount Ingalls and west of Red Clover Valley. There is a smaller area at the southwest base of Mount Ingalls east of Little Grizzly Greek, and also another just southwest of the last and on the west side of Little Grizzly Creek. It is the lava of Walker Plains, in Plumas county, and of Mooreville Ridge and Oroville Table Mountain, and the Iron Cañon

of Chico Creek in Butte county. So far as I am aware, this dense black older basalt is found only in Plumas and Butte counties. At numerous points it rests on Tertiary sediments, chiefly river gravels. It has nowhere been seen by the writer overlying or cutting through other Tertiary lavas. Its relation to the andesite (II) is very evident about four miles east-southeast of Mount Ingalls on the ridge to the east of the road from Red Clover Valley to Genesee Valley. Here a nearly horizontal bluff of andesite above five hundred feet vertically above the road may be seen resting on the older basalt (III). A vertical section here would be approximately as follows:

1. Andesitic breccia, thirty feet in thickness. This is made up of angular fragments of andesite cemented by volcanic ash. It shows no evidence of stratification. A little to the east of the bluff, lying on this breccia and presumably weathered from it, were found fragments of silicified wood.

2. Fine even-grained andesitic tuff, one to four feet thick. The tuff layer is approximately horizontal. It is made up of minute fragments of plagioclase, augite, hypersthene, green hornblende, and apparently some quartz, with opaque and discolored particles. It is very plainly fragmental. It contains also fragments of plant stems.

3. Andesitic conglomerate, fifteen feet thick. Immediately under the tuff and plainly resting on the older basalt is a volcanic conglomerate containing some fragments of the older basalt as well as granite pebbles but chiefly made up of pebbles and fragments of andesite.

4. Older basalt, five hundred feet thick. This reaches from the bluff of the above fragmental materials 1, 2, and 3, down to Red Clover Creek below, a vertical distance of about five hundred feet.

To the observer it is very manifest at this locality that the above series of volcanic fragmental rocks are of later date than the underlying basalt. The great thickness and extent of the basalt and the thinness of the overlying andesite renders it extremely unlikely that it is an intruded sheet. Moreover, the same superposition of the andesite on the older basalt may be noted at other points, as for example, at the southwest base of Mount Ingalls, at Iron Cañon in Butte county, and on the ridges to the north and south of Onion Valley Creek, in Plumas county. It is most probable that a period of erosion occurred between the time of the older basalt flows and that of the andesitic eruptions.

IV. *Rhyolite.*—A small area of this rock was noted four miles to the southeast of Mount Ingalls, to the west of Red Clover Valley. The exposure is surrounded by andesitic

breccia. Wherever in the Sierra Nevada its relation to the andesite is evident, it is the older rock. The relative age of the rhyolite and the older basalt has not been made out. I have nowhere seen them in juxtaposition.

It is expected that the above rocks will be studied in more detail later, with the aid of chemical analyses, so that their exact position in the series of Tertiary lavas may be determined. The subject is of especial interest in relation to Richthofen's law of succession of volcanic rocks, to which this forms an apparent exception.

The subject of the succession of the igneous rocks of the Great Basin has been considered in detail by Hague in the forthcoming monograph of the U. S. Geological Survey on the Eureka District, Nevada, and by Iddings* who states that igneous rocks of a mean composition are usually followed by both highly basic and highly acid types.

The Tertiary lavas of Mount Ingalls rest on a base of much older rocks, schists, metamorphic tuffs and granite. The latter rock is of igneous origin, as is shown by the inclusions in it of the older clastic rocks which are here in part at least, of Carboniferous age. These inclusions are numerous at a point on the southwest slope of the mountain, three miles from the summit.

Since writing the above, the following analyses have been obtained:

	Older basalt (No. 276.)	Late basalt (No. 311.)
SiO_2	50·56	53·91
TiO_2	1·71	·52
Al_2O_3	14·71	17·95
Fe_2O_3	3·54	2·21
FeO	8·90	4·80
MnO	·13	·10
CaO	7·58	10·40
SrO	trace?	trace.
BaO	·25	·05
MgO	4·07	5·52
K_2O	2·10	1·34
Na_2O	2·94	2·90
Li_2O	trace?	trace.
H_2O at 100° C.	1·06	·20
H_2O above 100 C.	1·12	·20
P_2O_5	1·14	·21
	99·81	100·31

* "The Origin of Igneous Rocks," by J. P. Iddings, Bull. Phil. Soc. Washington, vol. xii, pp. 89–214.

The analyses were made by W. F. Hillebrand of the U. S. Geological Survey. It will be noted that the two basalts, so different in age and in habitus, are quite similar in composition. As would be expected in the dense black older basalt containing a large amount of magnetite, the iron contents are much greater than in the coarse-grained gray basalt of later age.

Washington, D. C., Sept. 9, 1892.

ART. LXI.—*A Method for the Quantitative Separation of Barium from Strontium by the action of Amyl Alcohol on the Bromides;* by PHILIP E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College—XIX.]

THE existing methods upon which dependence can be made in the separation of barium from strontium are few in number. Dr. R. Fresenius in discussing them through several numbers of his journal* concludes that the only one which gives perfectly reliable results consists of the precipitation of the barium by a double treatment with ammonium chromate in acetic acid solution. Having demonstrated the possibility of separating both barium and strontium from calcium by the dehydrating and appropriate solvent action of boiling amyl alcohol on the nitrates† the possibility of a similar method of separation by the use of suitable salts of barium and strontium seemed worthy of investigation and necessary to complete the series as applied to this group. In looking about for suitable salts upon which to experiment the behavior of the chlorides was suggestive. Barium chloride is completely insoluble in amyl alcohol while the corresponding strontium salt is somewhat soluble. The possibility of finding strontium bromide more readily soluble than the corresponding chloride seemed worthy of attention. The method of preparation followed was the treatment of the precipitated and thoroughly washed carbonates of barium and strontium with hydrobromic acid prepared‡ by mixing definite proportions of potassium bromide in solutions with sulphuric acid and water while hot, filtering off the potassium sulphate which separates on cooling, and redistilling the filtrate until the distillate contains no appreciable trace of sulphuric acid. The standards of the solutions of barium and strontium bromides made in this way were determined by precipitating definite portions, measured and weighed, with sulphuric acid,—the strontium after the accepted method of adding ethyl alcohol to increase the insolubility and the

* Zeitschrift für Anal. Chem., xxix, 20, 143, 413.
† This Journal, xliii, 50, 314. ‡ Proceedings Amer. Acad., xvii, 30.

barium after the manner suggested by Dr. F. W. Mar,* precipitating with an excess of sulphuric acid in the presence of hydrochloric acid. The mean of closely agreeing results was taken as the standard. Preliminary experiments on the bromides formed in this way gave encouraging results, the barium salt appearing to be almost completely insoluble while the strontium salt dissolved freely. The first series of experiments were directed toward a quantitative determination of the solubility of barium bromide in the alcohol. Definite portions of the standardized solution of barium bromide were measured from a burette into counterpoised beakers of about 50 cm^3 capacity and weighed as a check on the burette reading. This solution was then evaporated to dryness, and the residue was dissolved in a few drops of water and boiled with 10 cm^3 of amyl alcohol. The separating bromide was filtered off on an asbestos felt contained in a perforated platinum crucible, the whole having been previously ignited and weighed. The crucible containing the bromide was at first dried at 140°–150° C. in an air bath after the manner described in the previous papers, and weighed. The unsuccessful attempt to get a constant weight, however, proved the impossibility of weighing as bromide, the weight decreasing rapidly with each successive drying. It was deemed best accordingly to dissolve the bromide from the felt into a beaker placed to receive it, and to precipitate with sulphuric acid in the presence of hydrochloric acid, after the same manner followed in the determinations of the standards. The precipitated sulphate, which in a few minutes settles completely, was filtered off upon the same felt from which the bromide had been dissolved, dried, ignited to low redness, and weighed. Series I gives the results of several experiments made after this manner which show the solubility of the barium salt to be about 0·0013 grm. on the oxide in 10 $cm.^3$ of amyl alcohol. The filtrate after boiling with amyl alcohol was evaporated and the residue was treated with sulphuric acid and weighed; or the filtrate was precipitated directly by adding sulphuric acid, enough ethyl alcohol being added to secure thorough mixture. The amount of sulphate found agreed uniformly with the loss determined in the residue after boiling. A portion of the salt which dissolved in the alcohol on being examined before the spectroscope gave only the green bands characteristic of barium.

SERIES I.

	BaO taken.	BaO found.	Error.
(1)	0·1234 grm.	0·1222 grm.	0·0012— grm.
(2)	0·0824 "	0·0809 "	0·0015—
(3)	0·0823 "	0·0809 "	0·0014—
(4)	0·0818 "	0·0803 "	0·0015—
(5)	0·0733 "	0·0720 "	0·0013—

*This Journal, xli, 288.

Several methods of treatment were followed to prevent if possible this solubility, such as the addition of a few drops of hydrobromic acid before boiling, of the same after the barium bromide had separated, of a few drops of ethylene dibromide or ethyl bromide at the completion of the boiling, of a few drops of bromine water before boiling, etc. The results of these experiments showed these modifications to be of little or no value.

On boiling the strontium bromide with the alcohol slight spots separated occasionally, which on the addition of a drop of hydrobromic acid went into solution and did not appear on re-boiling. In order to determine the solubility of the strontium bromide in the alcohol a saturated solution was obtained by boiling an excess of the strontium salt with the alcohol, the salt in a measured portion of 10 cm^3 was precipitated as sulphate by the addition of ethyl alcohol, and sulphuric acid, and weighed. Duplicate determination showed the solubility to be about 0·2 gram on the oxide in 10 cm^3 of the alcohol. The mode of procedure for the separation of these elements was identical with that already described in the case of barium alone up to the point at which the barium was filtered off, except, of course, the addition at first of a measured and weighed amount of a previously standardized solution of strontium bromide. The strontium was precipitated from the filtrate as sulphate by dilute sulphuric acid, ethyl alcohol being added to secure thorough mixture. These precipitates were generally filtered off upon asbestos felts, and, although their gelatinous character delayed the filtration somewhat, the drying and burning of a filter paper with the possible danger of loss by reduction in the presence of burning paper was avoided. Series II gives the results of a single treatment, and it will be seen that there is apparently a slight contamination of the barium by the strontium which where the latter is present in large quantities balances the solubility of the barium (0·0013 grm. on the oxide.) Where the amounts of strontium taken are small the loss of barium due to solubility appears.

SERIES II.

	BaO taken. grm.	BaO found. grm.	Error. grm.	SrO taken. grm.	SrO found. grm.	Error. grm.
(1)	0·1228	0·1225	0·0003—	0·1070	0·1065	0·0005—
(2)	0·1227	0·1231	0·0004+	0·1074	0·1069	0·0005—
(3)	0·1224	0·1228	0·0004+	0·1070	0·1067	0·0003—
(4)	0·1217	0·1201	0·0016—	0·0364	0·0372	0·0008+
(5)	0·1216	0·1222	0·0006+	0·0133	0·1124	0·0009—
(6)	0·0974	0·0970	0·0004—	0·0719	0·0721	0·0002+
(7)	0·0971	0·0973	0·0002+	0·0730	0·0727	0·0003—
(8)	0·0970	0·0971	0·0001+	0·0718	0·0716	0·0002—
(9)	0·0411	0·0390	0·0021—	0·0365	0·0385	0·0020+
(10)	0·0243	0·0234	0·0009—	0·1072	0·1072	0·0000

Series III gives the result of a double treatment. In this series the contaminating effect of the strontium salt disappears almost entirely leaving a deficiency of about 0·0025 grm. on the oxide to be added to the barium, and a corresponding amount of sulphate (0·0040 grm.) to be subtracted from the strontium sulphate before calculating it to the condition of the oxide. The manipulation is the same as that outlined for the single treatment, as far as the completion of the first boiling. At this point the amyl alcohol containing most of the strontium in solution was decanted upon a weighed and ignited felt and collected in a beaker placed to receive it. The residue of barium with traces of strontium was then dissolved in a few drops of water, a drop of hydrobromic acid was added and the boiling was repeated with another portion of 10 cm^3 of amyl alcohol. Upon reaching the boiling point of the alcohol the beaker was removed, and the barium salt was filtered upon the felt through which the first portion had been decanted, and treated as before described.

Series III.

	BaO taken. grm.	BaO found. (Corrected.) grm.	Error. grm.	SrO taken. grm.	SrO found. (Corrected.) grm.	Error. grm.
(1)	0·1212	0·1219	0·0007+	0·1068	0·1071	0·0003+
(2)	0·1215	0·1219	0·0004+	0·0358	0·0359	0·0001+
(3)	0·1220	0·1221	0·0001+	0·0353	0·0347	0·0006—
(4)	0·1212	0·1220	0·0008+	0·0363	0·0358	0·0005—
(5)	0·1219	0·1221	0·0002+	0·0361	0·0354	0·0007—
(6)	0·1211	0·1218	0·0007+	0·1126	0·1116	0·0010—
(7)	0·1319	0·1319	0·0000	0·0577	0·0586	0·0009+
(8)	0·0496	0·0492	0·0004—	0·0574	0·0579	0·0005+

The method is rapid, and while the correction to be applied owing to the solubility of the barium salt is large it is so definite that it cannot be objectionable. The author in conclusion would express his indebtedness to Prof. F. A. Gooch of the Kent Laboratory for the many helpful suggestions received from him bearing upon this investigation.

Art. LXII.—*A Note on the method for the Quantitative Separation of Strontium from Calcium by the action of Amyl Alcohol on the Nitrates;* by Philip E. Browning.

[Contributions from the Kent Chemical Laboratory of Yale College—XX.]

Recent work on my method for the quantitative separation of strontium from calcium by the action of amyl alcohol on

the nitrates* has demonstrated the possibility of using very much smaller amounts of amyl alcohol in the boiling than the amounts formerly used (30 cm³ for each treatment). By the use of smaller beakers (50 cm³ capacity) 10 cm³ of the alcohol can be conveniently substituted for 30 cm³, and the correction for solubility of the strontium nitrate is thus reduced from 0·001 grm. on the oxide to 0·0003 grm. in each treatment, and the corresponding amount of sulphate to be substracted from the calcium sulphate before calculating to the condition of oxide is reduced from 0·0017 grm. to 0·0005 grm. in each treatment. The necessity of a double treatment, or the use of two portions of 10 cm³ each of the alcohol, brings the total correction to 0·0006 grm. on the strontium oxide, and 0·0010 on the calcium as sulphate. For ordinary work such a correction may be disregarded. The following tables give the corrected and uncorrected results.

TABLE I (correction disregarded).

	SrO taken. grm.	SrO found. grm.	Error. grm.	CaO taken. grm.	CaO found. grm.	Error. grm.
(1)	0·0570	0·0565	0·0005 —	0·0534	0·0540	0·0006 +
(2)	0·0573	0·0567	0·0006 —	0·0534	0·0543	0·0009 +
(3)	0·0285	0·0274	0·0011 —	0·0272	0·0276	0·0004 +
(4)	0·0568	0·0560	0·0008 —	0·0535	0·0537	0·0002 +
(5)	0·0568	0·0561	0·0007 —	0·0533	0·0535	0·0002 +
(6)	0·0288	0·0280	0·0008 —	0·0271	0·0272	0·0001 +
(7)	0·1420	0·1416	0·0004 —	0·0535	0·0544	0·0009 +
(8)	0·1419	0·1416	0·0003 —	0·0665	0·0669	0·0004 +
(9)	0·1135	0·1132	0·0003 —	0·1066	0·1070	0·0004 +
(10)	0·1137	0·1126	0·0011 —	0·1064	0·1070	0·0006 +

TABLE II (correction applied).

	SrO taken. grm.	SrO found. (Corrected.) grm.	Error. grm.	CaO taken. grm.	CaO found. (Corrected.) grm.	Error. grm.
(1)	0·0570	0·0571	0·0001 +	0·0534	0·0536	0·0002 +
(2)	0·0573	0·0573	0·0000	0·0534	0·0539	0·0005 +
(3)	0·0285	0·0280	0·0005 —	0·0272	0·0272	0·0000
(4)	0·0568	0·0566	0·0002 —	0·0535	0·0533	0·0002 —
(5)	0·0568	0·0567	0·0001 —	0·0533	0·0531	0·0002 —
(6)	0·0288	0·0286	0·0002 —	0·0271	0·0268	0·0003 —
(7)	0·1420	0·1422	0·0002 +	0·0535	0·0540	0·0005 +
(8)	0·1419	0·1422	0·0003 +	0·0665	0·0665	0·0000
(9)	0·1135	0·1138	0·0003 +	0·1066	0·1066	0·0000
(10)	0·1137	0·1132	0·0005 —	0·1064	0·1066	0·0002 +

* This Journal, xliii, 50.

ART. LXIII.—*A Study of the Formation of the Alloys of Tin and Iron with descriptions of some new Alloys;** by WILLIAM P. HEADDEN.

ABOUT three years ago I had occasion to investigate some tin buttons obtained in assaying tin ore by the potassic cyanide method, and observed that the alloy obtained by oxidizing the buttons with hydric nitrate and treating the oxidized mass with potassic hydrate was not only significant in quantity, ranging from one and a half to ten and a half per cent, but varied in form also, though obtained under similar conditions of charge and temperature. Subsequent investigations convinced me that the same is true of dross obtained by melting larger quantities of tin ore with anthracite dust, lime and fluor spar in a graphite pot. As the latter method yields larger quantities at less expense, the dross from such fusions was used, as a rule, in my investigations.

Of the buttons first investigated, the first yielded about 7 per cent of a non-magnetic alloy corresponding to the formula Fe_2Sn_3; the second yielded a quantity of magnetic alloy corresponding to the formula Fe_4Sn_5; while the third yielded a non-magnetic alloy, so small in quantity, however, that no analysis was attempted, but its form differed from that of the other two, and I had no reason for believing it to be identical with either of them. Its form was that of a six sided prism with etched and pitted basal plane which was seldom perfect though always present. This was probably an imitative form after an orthorhombic combination.

The results of the investigation to which this led may be briefly given as follows: i. e. that there is a series of stannides of iron of which I obtained the following members, $FeSn_2$, Fe_2Sn_3, Fe_2Sn_4, Fe_4Sn_5, Fe_5Sn_6 and FeSn—and in addition to these, the following, Fe_3Sn, Fe_4Sn and Fe_2Sn.

Some of these have been described before, but the descriptions given by the various investigators agree in assigning them properties, some of which differ widely from those observed in my alloys. Those previously described are $FeSn_2$, Noellner; FeSn, Deville and Caron; Fe_3Sn, Lassaigne, and Fe_4Sn, Bergman. The first of these has more recently been studied by A. C. Oudemann, Jr. Noellner says that $FeSn_2$ is insoluble in hydric chloride. While Oudemann makes no definite statement on this point, merely stating that he prefers to use hydric nitrate in separating it from the excessive tin leaving it to be inferred that he found it at least difficultly

* Abstract of article read before Colo. Scientific Society—Address of retiring President for 1891.

soluble in the hydric salt. Deville and Caron describe FeSn as insoluble in hydric chloride and crystallizing in plates. The alloys which I have obtained, giving these formulas, do not agree with these descriptions. All writers on these alloys agree in giving aqua regia as the solvent for them. I have uniformly used hydric chloride and have found but a small amount of any one of them insoluble in this agent, and the portion insoluble in it was almost as insoluble in aqua regia. The description of forms is also quite at variance. This may be due to difference of interpretation of the forms, or it may indicate that these alloys vary greatly, both in form and properties according to the conditions under which they are formed; my observations tend to establish the latter. The compounds Fe_2Sn_3, Fe_3Sn_4 and Fe_4Sn_5 vary in their property of being magnetic, sometimes being almost or quite non-magnetic, and it will require a more exhaustive study of their crystal form to establish any distinctive difference between them in this respect; the habit of the crystals as obtained is, it is true, somewhat different, but it is doubtful whether it is uniform and persistent enough to be relied upon as distinctive. I have recognized but one form with certainty, a rhombic prism, which is the crystal form of the alloy $FeSn_2$. Though some crystals of this form were observed which have not been proven to be this alloy and this form may be common to several alloys. Furthermore certain rough six-sided imitative forms have been observed, which are not characteristic of any one of at least three alloys. These facts indicate as already suggested, that the various observations may not be contradictory because made on material which is not perfectly comparable.

The members of this series are all brittle, so much so that in the form in which they were obtained, they can be rubbed to a powder between the thumb and finger; they all burn, readily and quite brilliantly, when strewn into the flame of a candle or alcohol lamp with the formation of a dense smoke, and the emission of an intense odor of tin, best observed a short distance above the flame. This odor was so intense and similar to that of arsenic that it was with difficulty, and only after repeated experiments, that I convinced myself of the absence of this element.

These alloys require so high a temperature to fuse them that I was able to fuse only small portions of them before the blowpipe, and that not very satisfactorily; whether they suffered decomposition thereby was not evident, but with soda on charcoal they were decomposed with emission of sparks and the separation of malleable tin. Concentrated hydric sulphate acts upon them violently with copious evolution of sulphur dioxide.

That iron and tin readily unite with one another is well known, but the character of the iron and the temperature are important factors. When reduced iron was used the combination ensued quickly and the solution of the iron in the tin was perfect, but when cast iron was used this was not the case; but the presence of the carbon did not prevent the formation of these alloys.

Whether these alloys can endure remelting without decomposition or not was not decisively proven, but the experiments made tend to show that they can be melted by themselves and kept at a temperature sufficient to melt cast iron for an hour without perceptible decomposition, and if melted with tin already saturated with the alloy they may be remelted several times without material change, at least within the limits of temperature under which my experiments were made. While it is evident from my experiments that the frequent remeltings to which the reguluses were subjected had at most only a very subordinate influence in determining the alloy formed, it is equally evident that the influence of the ratio of tin to iron is very great; it appearing to be the determinative condition in the formation of the series from FeSn to $FeSn_2$, but for the alloys Fe_2Sn, Fe_3Sn and Fe_9Sn it would seem that we will have to look for some other condition as the ratio of iron to tin alone will evidently not suffice in explaining their formation.

It is probable that the alloy first formed during the reduction is not that with the highest ratio for the tin, as is indicated by the results of the investigation of the buttons from the cyanid assay which had not been remelted and some of them had been in the fire but eight minutes and still yielded the intermediate members of the series which according to our observations are formed between wide limits in the ratio of tin to iron, and this too when the atomic ratios of the iron to tin in the buttons was such as to justify the expectation of finding an alloy having a higher tin ratio. It is difficult to say in which experiment we approached most nearly to the conditions existing in the original mass of tin but probably in the first in which the regulus resembled pure tin but yielded an alloy having the ratio (Fe : Sn) 1 : 1; in another in which case the fusion was effected at a higher temperature and continued longer the alloy had the ratio of 1 : 1·25; but in this case we had a small amount of a very rich iron alloy with the approximate ratio of 9 : 1 separated from the regulus which might have had some influence upon the ratio of the alloy, especially if this iron alloy is a product of the decomposition of alloys richer in tin which already existed in the mass which, however, I hold to be doubtful. In still another the alloy obtained had the ratio of 1 : 1 and there was a large por-

tion of iron alloy or bottom with the ratio 4 : 1 and in a fourth one the alloy had the ratio of 1 : 1 though the bottom amounted to over 33 per cent of the weight of the regulus. An examination of the ratios of the alloys yielded by the different reguluses shows that the presence of an iron bottom does not necessitate the lowest ratios for the tin; for in such cases we have the ratios 100, 1·20, 1·25, 1·33, and 1·5 nor does its absence indicate the highest ratios; for in such cases we have the same ratios as before,—still, in a general way, those reguluses having an iron bottom yield alloys with lower ratios than those which have none, but the difference is neither decided enough, nor sufficiently constant to justify the conclusion that they are end-products of a series of decompositions, with successive eliminations of tin and consequent enrichment of iron in the alloy. The ratio of the alloy depends upon the ratio of the iron to the tin in the mass rather than upon any possible decomposition.

Some experiments were made with the object of building up the series from the lowest to the highest ratio with the following results. A quantity of dross containing the alloy FeSn was fused with one and a fourth times its weight of bar tin and the principal portion of the resulting alloy had the ratio of 1·25 but further changes also took place as indicated by such ratios as 1·33 and 1·66 obtained for smaller portions of alloys. When the atomic ratio of the iron to tin in the mixture was made as 1 : 6 the ratio of the alloy was changed from 1 : 1 to 1 : 1·33 and the same result was obtained when the tin in the mixture was increased so that the atomic ratio of the Fe : Sn was as 1 : 18. When I used the alloy Fe_3Sn_8 and the atomic ratio of the mixture was made 1 : 25, the ratio of the alloy was changed from 1 : 1·25 to 1 : 1·33; the same result was obtained by using the alloy FeSn and making the atomic ratio of the mixture 1 : 41, i. e. the ratio of the alloy was raised from 1 : 1 to 1 : 1·33; using the same alloy and making the ratio of the mixture 1 : 98 a mixed result was obtained the ratio was raised in part to 1·25 but principally to 2 but when the atomic ratio of the mixture was made 1 : 124 the ratio of the alloy, insoluble in hydric nitrate always understood was raised from 1 : 1 to 1 : 2. Equally satisfactory results were obtained when I used reduced iron "Ferrum reductum," instead of the alloys so long as I observed the ratios in the mixture, showing that the use of the alloy had no influence upon the result of the reaction.

It is evident that the ratio of Fe : Sn in the mixture has a determining influence upon the resulting alloy, also that the limits of this ratio for some of the alloys is quite wide especially for the alloys Fe_3Sn_4 and Fe_4Sn_5 but it seems that the formation of others is confined to narrow limits or peculiar

conditions as Fe_2Sn_3 which was found to be the chief alloy in only one instance, i. e. where the atomic ratio of the mixture was 1 : 22 and this is singular; for in other instances where the ratio was 1 : 25 and 1 : 41 respectively an alloy with a lower ratio, i. e. 1·33 was obtained and, moreover, 1 : 22 is the ratio given in Watts's Chemical Dictionary for a definite alloy. The regulus from which I obtained this alloy and having this ratio could not in any sense be considered an individual alloy.

I have not intended to even intimate that the whole of the iron in the reguluses obtained existed in the form of alloys difficultly or insoluble in hydric nitrate; for at least one alloy soluble in this agent and crystallizing in long and wide but thin plates was observed.

The temperature, duration of fusion, and rate of cooling are very subordinate in their influence upon the alloys formed both in regard to their properties and their distribution through the regulus.

The only alloy whose form could be definitely made out was the alloy $FeSn_2$ which crystallizes in bright shining rhombic prisms, being combinations of 001, 110, 010, from brownish black to black in color with metallic luster.

Another form is a six-sided often furrowed, almost always, if not always hollow form. This form is very interesting but not characteristic as it is common to several compounds.

The terms iron alloy and iron bottom have been used to designate a hard, gray and strongly magnetic mass forming the lower part of some of the reguluses and amounting in one case to rather more than one third of the same by weight. My analyses of these contain two errors which being in opposite directions about neutralize each other, only one of them, however, affects the ratio of the iron to tin when these are calculated to one hundred, i. e. the carbon which seriously impairs the value of the ratios obtained and it is no matter for surprise that only one of the analyses gives even an approximate ratio: the fact that the material analyzed had to be used just as it was taken from the crucible may account for this in part but it is a question whether these bottoms are other than gray cast iron alloyed with or containing varying quantities of tin. My experiments seem to prove that their formation does not depend upon the presence of a large quantity of iron, i. e. that they are not products of dissociation, but that the presence of carbon is absolutely necessary to their formation.

These compounds, which I have classed with the tin compounds despite this degree of uncertainty as to their true nature, demand our attention and awaken our interest even if they are related to cast iron, for they have been found to collect other compounds still to be described.

State School of Mines, Rapid City, S. D.

ART. LXIV.—*Notes on the Cambrian Rocks of Pennsylvania and Maryland, from the Susquehanna to the Potomac;* by CHARLES D. WALCOTT.

[Read before the Philosophical Society of Washington, Oct. 29, 1892.]

THE special study of the Cambrian rocks of the Southern Appalachians* was limited during the past field season to an examination of some of the more important exposures of the group in central Pennsylvania and Maryland. Within this area between the Susquehanna and the Potomac rivers two points have been the subject of investigation by geologists, and decided differences of opinion exist in regard to the stratigraphy and the geological age of the rocks embraced within them. One is that of South Mountain as it occurs in Franklin, Cumberland, York and Adams counties, in Pennsylvania. The second is the area about Harper's Ferry, Virginia. After an examination of the published literature, including geological sections and maps, it was decided to begin work in York county on the Susquehanna and to extend it southwest to the Potomac. Prior to this three days were spent at Mount Holly Springs, in the northwestern part of South Mountain, in a preliminary examination of the quartzites exposed at that point. The discovery of the lower Cambrian or Olenellus fauna in a synclinal trough near the western foot of the mountain, gave an important datum point which was afterwards of great service in work to the south in Franklin county.

York County.

Dr. Persifor Frazer considers the Lancaster limestones as probably the equivalent of the Calciferous and Trenton limestones of the New York series, and mentions that the York limestone is a slender offshoot.† The Hellam quartzite of York is called the "Chikis" quartzite, and is described as a basal formation upon which a series of schists occur that to the south "are, at all events, those slates in which the iron ores of Lancaster and York are invariably found, the transition series between the Primal and Auroral."‡ Professor Lesley describes in his final report§ the "Chiques" sandstone as the same formation as the Hellam quartzite of York county (as

* Notes on the Cambrian rocks of Virginia and the Southern Appalachians, this Journal, vol. xliv, 1892, pp. 52–57.

† 2d Geol. Survey of Penn. Report of Progress in 1877. Geology of Lancaster County, 1880, p. 4.

‡ Loc. cit., p. 7.

§ Geol. Survey of Penn. Summary Description of the Geology of Penn, vol. i, 1892, p. 165.

named by Frazer) and equivalent to the upper Cambrian quartzite of Walcott. He prefers to use the older name "Chiques" for these sandstones, stating that it is best to get rid of the old name "Potsdam" sandstone, as there does not seem to be any satisfactory evidence that the proper Potsdam sandstones of the Canada line and Lake Champlain extended as far south as southern Pennsylvania. He says that the section at "Chiques Rock" is not quite comprehensible at one or two points. I found that it was so complicated by thrust faulting that it is not a typical section. It exposes, however, the lowest of the Cambrian rocks now known to me in central Pennsylvania. The "Chiques Rock" proper, near Chiques, is the Scolithus quartzite, and is in an unbroken section at the summit of the series of the quartzites and slates of the Chiques section although now apparently at the base of the section. The quartzites to the south, between "Chiques Rock" and the limestones at Columbia, are older and have been raised up from beneath and thrust over on the Scolithus quartzite at "Chiques Rock." This is determined by the succession shown in the section exposed on the flanks of South Mountain, in Franklin county west of Monterey, reference to which is made in the notes on the geology of South Mountain. In relation to the stratigraphic position of the slates, etc., beneath the Lancaster limestone, I will quote the statement of Professor Lesley, "The geographical proof that the slates *overlie* the quartzite is complete; and establishes the correctness of Professor Rogers' *Upper Primal slate* formation. The geological evidence is equally conclusive; for the general dip in the Chiques rock is southward, under the slates; and of the slates southward under the limestone."*

The continuation of "Chiques Rock" to the westward, in York county, forms the Hellam hills† and shows a broad anticlinal of quartzite surrounded by schists. Numerous sections along the southern and western sides of the Hellam hills show that the quartzites pass beneath a series of shales, slates, sandy and calcareous layers that, in turn, pass beneath the limestones of the valley.

It was my good fortune to have the acquaintance of Prof. A. Wanner, superintendent of public schools at York. He volunteered to be my guide to localities where there were good exposures of the quartzites, schists and limestones, and he gave me valuable assistance. A reconnaissance was first made of the section at "Chiques Rock" south to Colum-

* Loc. cit., p. 172.

† I did not learn of any local name for this ridge of hills when in York county, and as most of the ridge is within the township of Hellam I shall speak of them as the Hellam hills.

bia, and then on the western side of the river from Wrightsville north to the quartzites. On the western side of the river the section appeared to be unbroken from the Hellam hills to Wrightsville, and to be as represented by Dr. Frazer* in his section along the right bank of the Susquehanna. In this the succession is from a quartzite (1) to shales (2) and to limestone (3), the latter in Wrightsville, at the Columbia bridge; the sandy shales and argillites (2) pass conformably beneath the massive limestone (3) which forms a deep synclinal fold before being cut off to the south by a fault.

The second section examined was No. 2 of Dr. Frazer's, extending from Emigsville south through Red Lyon station.† In the description of this section‡ he refers the sandstone in the railroad cut just north of Emigsville to the Triassic New Red sandstone. At the northern end of the cut he noted a fine-grained sandstone, dipping 15° west, north 52 degrees. To the southward of this he describes a calcareous, sandy, pink shale, dipping south 5°, east 20°. This is subjacent to 27 feet of blue, finely laminated limestone, with white streaks, upon which rests a red bed of calcareous conglomerate two feet thick: this in turn is subjacent to a belt of reddish shaly sandstone, nine feet in thickness, which is capped by 156 feet of arenaceous shales of a somewhat flaggy character.

He says: "There would seem to be, therefore, an anticlinal in the Triassic measures—the only instance of one recorded within the limits of this district. The contact line of limestone and Mesozoic sandstone lies within or just north of the town of Emigsville. The first recorded dip in the older formation when projected upon the line of section is 2,160 feet, or a little more than a third of a mile from the last dip."§ I mention the details of Dr. Frazer's section as it is the one which led me to the determination of the stratigraphic position in the geologic series of the Chiques quartzites and the York shales‖ which are subjacent to the Lancaster limestone.¶ The fault betweeen the Paleozoic (Lower Cambrian) rocks and the New Red sandstone of the Mesozoic occurs in the railroad cut, at the point indicated in Dr. Frazer's section as the crest

*Second Geol. Survey of Penn., 1876. Section 1, accompanying Report of Progress in the district of York and Adams counties for 1874.

† Loc. cit., Section 2. ‡ Loc. cit., p. 88. § Loc. cit., p. 89.

‖ The name York shale is proposed for the band of shales resting upon the quartzites surrounding the Hellam hills. It is peculiarly well developed in York county, and appears to be absent in many of the sections about South Mountain and about the same series of quartzites in Lancaster county.

¶ The term York limestone was proposed by Dr. Frazer for this limestone; but as he states that it is a prolongation of the Lancaster limestone into York county, and that it is more fully developed in Lancaster county, I think it best to retain the term Lancaster limestone, as it is hardly necessary to call the same limestone by two different names in adjoining counties.

of the anticlinal in the New Red sandstone. No such anticlinal exists. The southern leg of Dr. Frazer's anticlinal is formed of rocks that bear no resemblance to the Mesozoic Red sandstone, and fossils of lower Cambrian age are abundant in the nine feet of compact, fine grained sandstone described by him. The section, from the fault line southward, is as follows:

	Thickness. Feet.
1. Gray, banded and mottled limestones, with purplish bed of limestone at summit three feet thick. This limestone weathers into a more or less arenaceous shale. Strike, E. & W. (Mag.) Dip, 25° S.	33
2. Gray and buff sandy shales passing (at 21 feet) into shaly sandstone and then into sandy shale, where a belt of calcareous quartzite occurs in layers varying in thickness from 2 to 12 inches	105
Fossils:—*Camerella minor*, and fragments of Olenellus, showing portions of the head and thoracic segments.*	
3. From the fossiliferous beds just mentioned, for a distance of 500 feet the hillside on the east of the railroad is covered with the debris of sandy shales, and several exposures occur along the wagon road. From the last of these to the first outcrop of limestone, a distance of 250 feet, the debris of sandy shales and thin-bedded calcareous quartzite occur abundantly in the southward-facing hillslope. As the last observed dip was 25° S., it is assumed that the section is unbroken, and a thickness is assigned to this division of	315
Fossils:—Numerous fragments of Olenellus and casts of *Camerella minor* occur in the calcareous quartzite interbedded in the shale.	
4. Massive-bedded, dove colored, banded limestones. Strike N. 20° W. (Mag.) Dip, 25° S.† near base of series. Although the section is more or less concealed by soil, numerous outcrops occur in quarries to the south. These show a banded limestone in the lower portion of the section with numerous irregular, small, concretionary bits of limestone, usually elongated with the bedding plane. The average dip of the beds is from 20° to 25° S. A beautiful section is shown in a quarry about one-fourth of a mile east of Emigsville, and in a quarry on the turnpike west of the railroad in the outskirts of the town. A little higher up in the section the limestones are massive, light colored, and, in places, almost a white crystalline marble.	

* On the line of strike of these beds, two miles northwest of Emigsville, the following fauna was found in the calcareous sandstones: *Camerella minor*, *Obolella crassa*, *Hyolithes communis*, and fragments of Olenellus.

† Dr. Frazer's section indicates a dip of 85°. I was not able to discover the locality where he observed it.

At a quarry in a field east of the railroad track and near where the roadway turns to the eastward towards Codorus creek, the strike of the limestone is N. 15° W. (Mag.), and dip 15° S. One of the layers is quite fossiliferous and gave fine specimens of a species of Salterella and Kutorgina, heads of small trilobites of the genera Solenopleura and Zacanthoides, and numerous fragments of the head and thoracic segments of a species of Olenellus.

Further to the westward in an old quarry east of the Northern Central R. R. track, massive layers of limestone are shown that have a strike N. 20° W. (Mag.); dip 20 S., and contain fragments of the genus Olenellus and Protypus. The next higher exposure in the section is in a large and deep quarry just west of the R. R. track, between one-fourth and one-half mile south of Emigsville. About 60 feet of limestone is exposed. The strike is E. and W. (Mag.), with a dip of 10° to the south. In the lower portion of the quarry there are massive layers of arenaceous limestone, and about ten feet from the summit of the section, alternating bands of earthy and pure limestone in which numerous fossils occur. In the collection obtained I have recognized:

Plates of Cystids.
Kutorgina, n. sp.
Orthisina festinata Billings.
Olenellus (fragments).
Protypus senectus Billings.

The fragments of Olenellus indicate individuals as large as any known. The fossils range through about twenty to twenty-five feet of the limestone. The layers above the fossiliferous band are largely brecciated and form a limestone conglomerate. The estimated thickness of the entire series of limestone is 750

In the railroad cut the limestone is shown, and, a little to the south of them, cleaved slates the bedding of which strikes east and west (Mag.) and dips 10° south. There is an interval of 20 feet between the limestone and slates covered by debris. The limestone appears to pass beneath the slates, and from the areal distribution of the slates and limestone to the south and southwest it is probable that this upper band of slates has a wide distribution; its thickness is unknown.

An area of quartzite, No. 2 of section, is colored on the map two miles N. W. of Emigsville as of the same age as the Hellam quartzite. It is, as we now know, a thinner belt of quartzite resting in the calcareous and sandy shales above the quartzite of the Hellam hills. The next point determined was the actual relation of the Olenellus quartzite at Emigs-

ville with the massive Scolithus quartzite of the Hellam hills. In passing from Pleasureville towards York, on the steep side hill two miles west of York there are exposures in the roadside of shales and calcareous sandstone above the massive quartzite of the Hellam hills. At a point probably 100 feet beneath the ferriferous shale in which the numerous ore pits occur on the south side of the Hellam hills, a species of *Obolella*, very closely allied to *Obolella crassa*, and fragments of Olenellus were found in the decomposed calcareous sandstone. At a locality about one mile south of Mt. Zion church, in Hellam township, and four miles northeast of York, numerous specimens of *Camerella minor* and fragments of Olenellus occur in a calcareous quartzite identical in character with that of the Emigsville section. These two localities prove that the Scolithus quartzites of the Hellam hills and of "Chiques Rock" are beneath the Olenellus calcareous quartzite of the Emigsville section and, therefore, of Lower Cambrian age.

Search was next made for fossils near the base of the limestone above the ferriferous shales resting on the quartzites of Hellam hills. They were found at a short distance above the shales in a small quarry of thin-bedded limestone by the roadside, one and one-eighth miles north of Stoner's station on the York & Wrightsville railway. The strike is a little north of west, and dip 45° south. Finely preserved specimens of Linnarssonia, closely allied to *Linnarssonia sagittalis* are abundant, and easily recognized fragments of a species of Olenellus are associated with them. Crossing the section to the south, occasional exposures were seen of massive bedded, light-colored limestones, much of the same character as those exposed in the quarries north of Wrightsville three miles to the eastward. The dip increased to 85° at the railroad track, which indicated that a compressed synclinal had been passed over in the section. The only locality where fossils were found within the main body of the limestone in York County was one and one-half miles southwest of the public square at York, Pa., on the north side of Highland Park. The species recognized are: one closely allied to *Olenoides Marcoui*, *Protypus senectus*, and two species of Ptychoparia, all of which belong to the Lower Cambrian fauna. When examining the section on the east side of the Susquehanna, in Lancaster county south of Columbia and north of Washington Manor, with Messrs. A. Wanner and Arthur Keith, a locality of lower Cambrian fossils was found in a narrow belt of limestone about half a mile north of Washington Manor. *Hyolithes communis* and fragments of Olenellus showing portions of the head and thoracic segments were recognized in the material collected.

A glance at Dr. Frazer's map of York county shows that it is probable that all of the limestones, quartzites and schists of the central portion of the country are of Lower Cambrian age. The Hellam quartzite ridge is, as stated by Dr. Frazer, evidently an anticlinal ridge broken on the northwest side by a fault that has brought the quartzite up against the higher horizons of the shales and limestones The anticlinal structure apparently extends to the southwest past York and towards Hanover.*

The discovery of Lower Cambrian fossils in the compressed synclinal of limestone in Lancaster county, south of Columbia, indicates that the limestone on the west side of the river is of the same geological age; and that the shales and schists beneath it (called chlorite schists, etc., by Frazer) are of Lower Cambrian age; and I doubt if there is a sedimentary rock,—other than the Mesozoic New Red sandstone—of later age than the Cambrian in York county, unless it may possibly be the Peach Bottom slate and chlorite schists of the southeastern corner of the county; and from the closely related structure of Lancaster county it is probable that all of the Lancaster limestones will fall within the Cambrian unless it be that some portions of the upper series of limestone may pass into the Ordovician. This generalization will also apply to the limestones of the adjoining counties of Berks and Chester and, in fact, to the entire extension of this series northeastward, to the Delaware. All of the quartzites, that have been referred to the Potsdam, will necessarily fall into the Lower Cambrian, as they are beneath the limestones.

When it is once considered that the quartzites, called the Potsdam by the Pennsylvania Survey, are of Lower Cambrian age; that a series of shales and limestones, superjacent to these, are of Lower Cambrian age: that the Potsdam horizon of the New York series is represented by limestones in the Auroral series of Rogers; and that the Calciferous-Chazy terrane of the New York section is represented only by the upper portions of the Auroral limestones, geologists will have little difficulty in determining the geologic horizons of the various outcrops of quartzites, schists, shales and limestones,—provided careful attention is paid to their sedimentary character and to the discovery of occasional localities of fossils.

South Mountain.

Prof. Lesley states that "the South Mountains," separating the Cumberland valley from the lower country of York and

*Southeast of the Hellam hills the limestones appear to form a compressed synclinal and this structure may extend to Hanover and beyond to the S.W. My time was too limited to study the details of structure off of the line of the sections mentioned in these notes.

Adams counties, form the northernmost end of the Blue Ridge range of Virginia. . . . . The whole measures upon the map ten miles in breadth by fifty in length upon a curve extending from the Maryland line to its eastern edge, fifteen miles west of Harrisburg.*

From the Pennsylvania line southwest across Maryland, South Mountain extends, as the Blue Ridge, to Harper's Ferry, and thence southwest across Virginia. It, also, practically includes the Cotoctin range, on the eastern side, which extends south from the southwestern portion of Adams county, Pennsylvania, and crosses the Potomac at the Point of Rocks, and from thence extends south a little west of Leesburgh, Va. The Blue Ridge and the Cotoctin Ridge are the eastern and western sides of the mountain uplift of which the South Mountain, Pennsylvania, is the northern terminus.

The classification of the rocks of Pennsylvania was summed up by Prof. H. D. Rogers as follows:—The Hypozoic rocks, or those *underneath* any life-bearing strata; Azoic, or those destitute of any discovered relics of life; and Paleozoic, or those entombing the remains of the earth's most extinct forms once living beings.†

It is evident from Prof. Rogers' definition of the Azoic group, that it included what we now recognize as the lower Cambrian sedimentary strata beneath the Scolithus quartzite and, also an extended series of altered rocks that form the nucleus of the Blue Ridge, and which are now included in the Algonkian of the classification of the U. S. Geological Survey. He regarded the sandstone with *Scolithus linearis* as at the base of the Paleozoic series, and considered that the Primal slates beneath the sandstone, and in intimate alternation with it, did not possess a vestige of organic life.

The conclusions of the geologists of the second geological survey of Pennsylvania, are that there are two groups of rocks forming South Mountain.

Prof. Lesley says: "The northwestern (Mt. Holly) ridge is made by several thousand feet of the lower quartzite and quartz conglomerate beds. The southeastern (Adams county) ridges are made by several thousand feet of an overlying feldspathic, micaceous and chlorite series, intersected by veins of milky quartz."‡ . . . . "It is hard to avoid the inference that our South Mountain rocks represent the Huronian section of Murray and Logan. It is impossible not to compare them also with

*Second Geol. Survey of Penn. A summary description of the geology of Penn., vol. i, 1892, p. 142.

†The Geology of Pennsylvania, vol. i, 1858, p. 64.

‡Second Geol. Surv. of Penn A summary description of the geology of Pennsylvania, vol. i, 1892, p. 144.

the great quartzite masses, the roofing slates, etc., of Walcott's upper, middle and lower Cambrian system."*

When I began the investigation to ascertain, by stratigraphic and paleontologic evidence, the geologic age of the South Mountain quartzite and the associated schists and slates, I soon discovered that there was very little prospect of finding the true geologic succession in the northern portion of the mountain, in Cumberland and York counties, owing to the folding of the strata and also to the fact that there were a number of westward thrusts of lower on higher beds, and that as a result of this the central core of the Blue Ridge had been broken and thrust over on the Lower Cambrian beds and, also, in places, resting apparently conformably upon the latter,—all having an eastward dip. The discovery of Olenellus with *Hyolithes communis* in the massive quartzite series in the Mt. Holly ridge, just above Mt. Holly Springs in Cumberland county, proved that the great western mass of quartzites of South Mountain, with the interbedded shales, slates and conglomerates, were of *Lower* Cambrian age; but it did not throw light upon the geologic age of the orthofelsite series of Frazer and the epidotic rocks of Rogers. In company with Mr. Arthur Keith, of the U. S. Geological Survey, who had mapped the Harper's Ferry sheet, an examination was made across the ridges, from Mechanicstown, Md., to Monterey and westward to Pikesville, in Franklin county, Pennsylvania.

On entering the gorge, a little west of Mechanicstown, on the line of the Western Maryland R. R., an extended series of shales and slates was passed,—all having a very high dip to the southeast. About two miles from Mechanicstown, massive quartzites were observed with a high dip to the east, and, higher up in the gorge, there was a repetition of the slates found east of the quartzites. This section, from the dip of the quartzite, indicated a synclinal resting on a considerable thickness of slates and shales. A series of sections, by Mr. Keith, of the western, or Blue Ridge ridge extending from a point eleven miles south of Mechanicstown to Harper's Ferry, shows that this same synclinal structure prevails all along the ridge, and that a synclinal fold of massive sandstone forms the summit of the ridge, below which a series of shales rests unconformably upon the subjacent crystalline rocks.† The synclinal structure is also shown for the quartzites of the eastern or Cotoctin ridge.

From a point two and one-half miles west of Mechanicstown to Monterey, the road led across the epidotic schists of

* Loc. cit., pp. 147, 148.

† The structure of the Blue Ridge near Harper's Ferry. Bull. Geol. Soc. America, vol. ii, 1891, pls. 4 and 5.

the central mass of the range, which is now a mountain valley between the Cotoctin and Blue Ridge ridges. The schist extends to a point one-fourth to one-half a mile beyond the Blue Ridge station, on the Western Maryland R. R. Fragments of a rhyolite-like, porphyritic rock* were also seen, that probably represent the "bedded petrosilex" of Dr. Hunt, as shown two miles south of this Monterey road, near Foxville, Maryland. Going down the road beyond Pen Mar towards Pikesville, there was an apparent repetition of the section on the eastern side of the ridge, near Mechanicstown. Subsequently, an examination was made of the section from Monterey, Franklin county, Pennsylvania, to the valley on the line of the Waynesborough turnpike. Just west of Monterey a massive quartzite forms a plateau, upon which the Monterey hotel is situated. The dip of the quartzite is slightly to the northwest. A short distance beyond the toll-gate the dip to the northwest increases, and a series of sandy and argillaceous shales succeeds the quartzite. Following down the turnpike toward Waynesborough and near the foot of the ridge, these shales were found to pass beneath a light-colored, hard, compact quartzite dipping northwest, in which numerous remains of *Scolithus linearis* occur. By breaking the white quartzite many fragments of Olenellus showing parts of the head and thoracic segments were also found. In calcareo-arenaceous layers, just beneath the quartzite, fragments of Olenellus occur associated with specimens of *Camerella minor*. A series of more or less sandy shales next appears resting upon the Scolithus quartzite and having a northwesterly dip, toward the valley. Along the foot of the ridge, low hills of sandy shale and slate appear, capped with a thin-bedded calcareous quartzite or sandstone. In the latter, *Camerella minor*, *Hyolithes communis*, and fragments of Olenellus are abundant. A little west of these hills the limestones of the valley appear. In this limestone, *Kutorgina* n. sp., and fragments of the head and thoracic segments of Olenellus were found a little east of the road leading up the east branch of Little Antietam creek, and about three miles east of Waynesborough.

If reference is now made to the York county section it will be seen that the upper portion of the Monterey section is essentially a repetition of it—from the Scolithus quartzite to the limestones of the valley. The same fossiliferous Scolithus quartzite passes beneath sandy shales and slates, in which are interbedded calcareous quartzites carrying the Olenellus fauna; these pass beneath the limestones of the valley in York county in which the Olenellus fauna occurs. In the Monterey

* The description of the volcanic rocks of South Mountain by Dr. G. H. Williams is contained in the following article, p. 482.

section, however, there is in addition a series of shales beneath the Scolithus quartzite, that rests upon a massive quartzite forming the summit of the Blue Ridge, west of Monterey and beneath this a bed of slates unconformable to the subjacent crystalline rocks.

The Blue Ridge was followed south into Maryland and crossed at several points before reaching Harper's Ferry. All of the section shows the synclinal structure of the slates and quartzites as represented by Messrs. Geiger and Keith, in their paper upon the structure of the Blue Ridge near Harper's Ferry.* South of Keedysville, Washington county, Maryland, the quartzite, capping the slate hills west of the main ridge, was observed to pass conformably beneath the limestone at Eakle's Mills, and *Hyolithes communis* and fragments of Olenellus were found in the calcareous quartzite. The relatively simple stratigraphic structure of the Monterey section is complicated at, and near, Harper's Ferry by the lower massive quartzite forming a synclinal and being thrust to the westward over the more recent shales, slates and limestones. The structure is still more complicated by the fact that the hills of sandy shale and slate (capped by the upper Olenellus quartzite) are thrust, on the line of a fault, over on to limestones which, in an unbroken section, rest upon the quartzites.

It was this primary folding and subsequent westward thrusting, on the line of two or more faults, of the older upon the more recent strata at and to the north and south of Harper's Ferry that led Messrs. Geiger and Keith to consider that the lower quartzites rested conformably upon the limestones and were of Silurian age.†

Returning to South Mountain with the information gained between the Potomac and the line of the Chambersburgh and Gettysburgh pike, in Pennsylvania, and studying Dr. Frazer's sections (Nos. 7, 8, 9, 10, 11 and 13)‡ and also reading the descriptions of them, as well as Professor Lesley's description of South Mountain (contained in Vol. I of his final report), it is evident that they have misinterpreted the true geologic structure of the mountain and the relations of the rocks composing it. Professor Lesley states that a massive fault must run along the foot of the mountain, along the low drift-filled valley of Yellow Breeches creek; and this I think is correct, as the Olenellus fauna of the Scolithus quartzite zone occurs but a short distance east of the foot of the mountain, in a syn-

* Bull. Geol. Soc. America, vol. ii, 1891, pls. 4 and 5.

† Loc. cit., pls. 4 and 5. A paper by Mr. Arthur Keith describing his present view of the structure will be found in the Dec. No. of the Am. Geologist for 1892.

‡ Second Geol. Surv. Pa. Report of Progress in the counties of York, Adams, Cumberland and Franklin for 1875 published 1877.

clinal fold, at Mt. Holly Springs. Their error, however, is in considering that the "orthofelsite" series is superior to the conglomerates, quartzites and schists which they referred to the Lower series. The Monterey section shows that the epidotic schists are inferior to the quartzites and slates and, a section west of Wolfsville, Md., that the "petrosilex" or rhyolite-like eruptive occupies a similar position. This type of section is repeated many times, both on the Cotoctin and Blue Ridge sides, from the Maryland line to the Potomac and south through Virginia.

Professor Rogers and also Professor Lesley, referred the offsets of the ranges of hills of South Mountain, as shown in Franklin county and also on the north end of South Mountain, to the terminations of successive folds of the rocks forming the mountain. My impression is that these offsets and also the complicated structure of the mountain arise partly from folding, but more largely from the westward thrusts of masses of strata along the line of faults of a low hade. This westward thrusting on the fault planes, complicated by previous foldings of strata, leaves masses of the subjacent pre-Paleozoic rocks resting, in various places, on different members of the lower Cambrian series, and also appears to interbed the quartzites and slates of the Cambrian in the schists, eruptives, etc., of the Algonkian.*

The key to the succession of the lower sedimentary rocks of Maryland and Pennsylvania is contained in the Balcony Falls section of Virginia, although it can now be determined by a study of the section at Monterey and to the south, along the Blue Ridge toward Harper's Ferry.

In a letter received from Professor Lesley and dated February 22d, 1891, he asks: "Is it impossible that there should be agreement between the Balcony Falls section of Virginia and the Mt. Holly Springs section, three hundred miles apart?" He says, further, after commenting upon the possible relations between the Balcony Falls section and that at South Mountain, in speaking of the strata of the Balcony Falls section: "But what is 2,000 feet or 2,500 feet to 10,000 feet to 20,000 feet of quartzites and slates making (apparently—not certainly—) the South Mountains? We are still in the dark about *super-* and *sub*-positions; about absence or presence of overturn rolls, etc. I am only greatly impressed with the broad fact that we seem

* From the finding of fragments of the eruptive rocks in the conglomerates at the base of the quartzite series, and from the numerous synclinals showing that the epidotic rocks and also certain rhyolitic eruptives are beneath the quartzite series I refer the similar rocks of South Mountain to a pre-Paleozoic age; and, as they are not of the character of the Laurentian crystalline complex, I would refer them to the Algonkian, but *not* correlate them with the Huronian or with any known division of that group of rocks.

to have the Huronian mass rising to view in the South Mountains of the Atlantic States."

I think that the view of Messrs. Frazer and Lesley that such great thicknesses of strata occur in South Mountain arises from the fact that these "great thicknesses" are but repetitions of both the Cambrian and pre-Cambrian strata from foldings and overthrust faultings and also from their not differentiating between the cleaved schistose eruptives of the Algonkian and the bedded and often cleaved sedimentaries of the lower Paleozoic.

The section at Monterey and along that portion of the Blue Ridge is roughly, as estimated from the data obtained by Mr. Keith to the south and from the Monterey section, reading from below upwards, as follows:

	Feet.
1. Shales and slates, well shown near Mechanicstown, Maryland, and in numerous sections along the Blue Ridge ..... 300 feet to	400
2. Coarse-grained and bluish-gray quartzite ..... 1000 to	1200
At several localities the shales of (1) appear to be replaced by bands of conglomerate and shale; and many of the layers of (2) are conglomeritic to a greater or less extent.	
3. Sandy shale, with interbedded layers of quartzite.....	800
4. Scolithus quartzite, with interbedded calcareous sandstones and shales.....	500
Fossils:—Camerella minor, and fragments of Olenellus.	
5. Sandy shales, with a series of calcareous quartzite near the summit; about	450
Fossils:—Camerella minor, Hyolithes communis, and fragments of Olenellus.	
6. Mottled limestone, with intercalated sandy and shaly layers .....800 to	1000
Fossils:—Kutorgina n. sp., and fragments of Olenellus.....	
This portion of the section is succeeded by the valley limestone, more or less of the lower portion of which is probably of middle and upper Cambrian age.	

The section includes from 3,000 feet to 3,500 feet of sandstones and shales before reaching the limestones. In a number of localities a conglomerate was observed in the Lower sandstone series, in which fragments of the pre-Paleozoic crystalline rocks were imbedded. This phenomenon was observed on South Mountain, in the conglomerates mentioned by Prof. Lesley, and also along the Blue Ridge and the Cotoctin ridge to Harper's Ferry; the conglomerate character of the rock

varying very much in the character and size of the coarser material. The feldspathic character of these shales and sandstones is very distinctly marked beneath the Scolithus quartzite, both in the Balcony Falls and the Monterey sections.

If these two sections are compared with that at "Chiques Rock" and south to Columbia, in Lancaster county, Pa., it will be at once observed that the Scolithus quartzite, while the highest band of quartzite in the Balcony Falls and the Monterey sections, is the lowest in the "Chiques Rock" section which has the lower feldspathic sandstone and shales apparently above the Scolithus quartzite. It is from this fact that it is stated, in the first part of this paper, that the feldspathic sandstones and shales were thrust over on the Scolithus sandrock in the "Chiques Rocks" section.

Art. LXV.—*The Volcanic Rocks of South Mountain in Pennsylvania and Maryland;* by George H. Williams. With Plate X.*

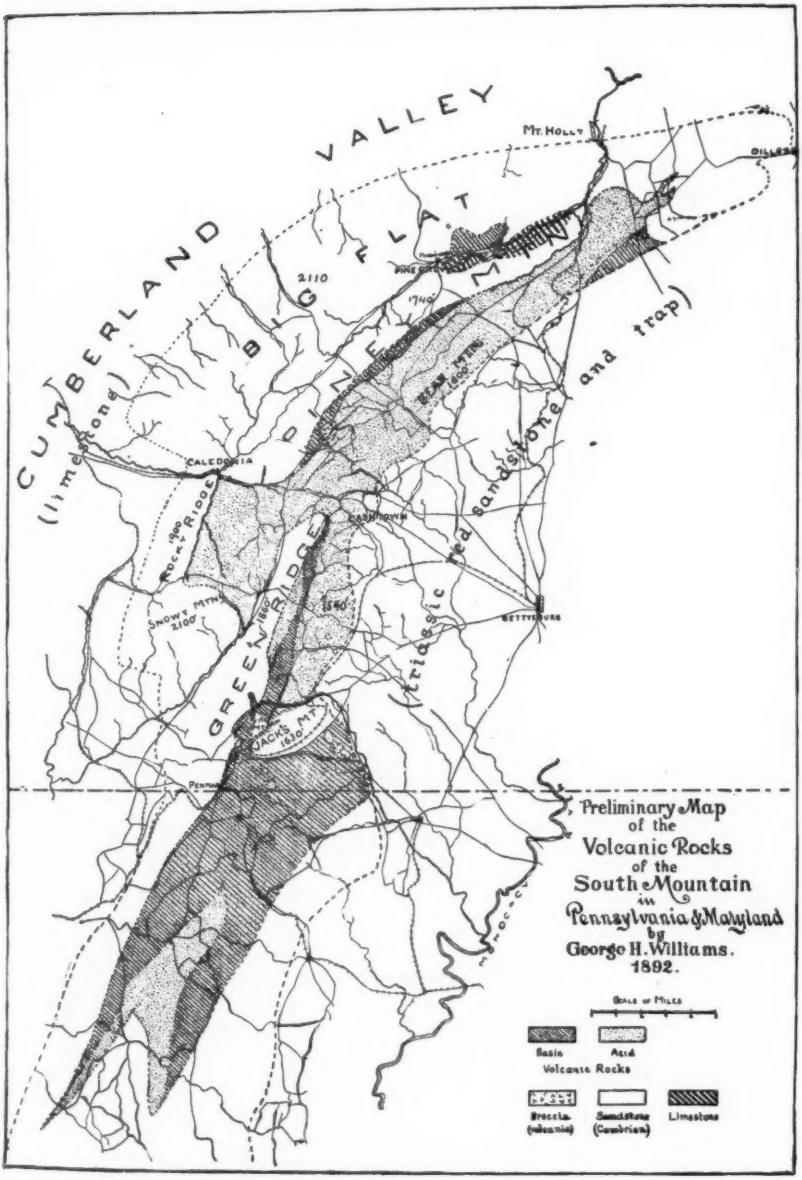
Contents.—1. Object of this paper. 2. Supposed sedimentary origin of the South Mountain volcanic rocks. 3. Petrographical character: *a*) The acid rocks —rhyolites; *b*) The basic rocks—basalts; *c*) The pyroclastic deposits—tuffs and breccias. 4. Geological occurrence and relations to the sandstone. 5. Chemical alteration and metamorphism. 6. Comparison with other regions.

[Read before the National Academy of Sciences, Nov. 2, 1892.]

1. *Object of this paper.*—It is the object of the present communication to announce the identification of an extensive area of very ancient volcanic rocks which compose an important part of the South Mountain, south of the Susquehanna River. The brief preliminary description of these rocks, which is all that can now be attempted, will, it is hoped, suffice to show that the hitherto accepted theory of their sedimentary origin has been based on a misinterpretation of the facts which they exhibit.

The rocks in question preserve abundant and convincing evidence—both structural, chemical, and petrographical—of their original character and genesis. At the same time they show various phases of alteration by recrystallization and dynamic agencies which render them valuable for the study of many problems of metamorphism.

* The writer is under great obligations for many of the facts contained in this paper to Miss Florence Bascom, who has mapped in great detail one of the most diversified portions of South Mountain, near Monterey, Pa. She has collected a large material upon which she is now at work at the Johns Hopkins University, and her results, to be published in due time as a thesis, will go far toward furnishing detailed proof of the general conclusions here set forth.


CUMBERLAND VALLEY
(limestone)
BIG FLAT MTN.
RIDGE
(Triassic red sandstone and trap)
GREEN RIDGE
Mt. Holly
Caledonia
Fairfield
Gettysburg
Penna
Md.
Snow's Mtn.
2100
Jacks Mt.
1630
Bear Mtn.
1600
2110
1740
1560
1800
1900
Preliminary Map
of the
Volcanic Rocks
of the
South Mountain
in
Pennsylvania & Maryland
by
George H. Williams.
1892.
Scale of Miles
Basic
Acid
Volcanic Rocks
Breccia
(volcanic)
Sandstone
(Cambrian)
Limestone

South Mountain rises about fifteen miles west of Harrisburg and extends, as may be seen on the accompanying map, in a great sickle-shaped curve to the Maryland line. Here it divides into two parts, known as Catoctin Mountain and the Blue Ridge, which diverge at a small angle and enclose the triangular Middletown valley, north of the Potomac.

During the past summer the writer devoted considerable time to mapping the volcanic rocks of this region and to collecting suitable material for laboratory study. This has at present only been fairly entered upon, so that subsequent communications giving more detailed results, may be expected.

2. *Supposed sedimentary origin of the South Mountain Volcanic rocks.*—As far as is known to the writer, volcanic rocks have not hitherto been definitely described as such in the Appalachians. The rocks here under consideration have long been known to geologists, but they have before, with the exception of a few of the most massive greenstones, been generally regarded as of sedimentary origin.

Professor Henry Rogers in 1858 speaks of South Mountain southwest of the Susquehanna, as embracing "a singularly small amount" of igneous rock. He alludes to the cleaved greenstones as "dark green slate," and to the acid porphyries and felsites as "highly metamorphic Primal slate." He continually contrasts the highly altered slate and the unaltered sandstone,* although in reality one rock is scarcely more changed than the other.

Philip Tyson, in his first report as State Agricultural Chemist made in 1860, speaks of the sandstone of South Mountain as Potsdam and says that it contains fossilized stems of plants. He also says: "A slate, varying in color from gray to brownish and greenish, is ranked as an argillite, but portions of it assume a marked talcose appearance, especially in Catoctin mountain, where it has been much disturbed and altered by proximity to intrusive rocks. These last consist of amphibolites (trap), porphyries, amygdaloid, serpentine and epidote."†

In 1877 appeared the results of Dr. Persifor Frazer's studies of South Mountain. He regarded it as composed essentially of a westerly (older) portion, consisting of various modifications of a quartz-conglomerate (Mountain Creek rock) and an easterly (younger) portion composed of orthofelsite, inter-

* Geology of Pennsylvania, vol. i, pp. 203–5, 1858.

† First Report of P. T. Tyson, State Agricultural Chemist, to the House of Delegates of Maryland, January, 1860, pp. 34, 35 (cf. also p. 18). In his second report (1862, p. 70) he gives further particulars regarding Catoctin Mountain. He says "a vast mass of epidotic trap, five miles wide, was forced up from below in a state of fusion. This embraces a mass of chert (rhyolite) 3000–4000 feet thick." He describes the trap as carrying metallic copper, and regards it as the cause of the elevation of the mountain sandstone.

bedded with hydromica and chloritic schists.* Regarding the origin of these latter rocks, which like the conglomerate were placed below Rogers' primal sandstone, Dr. Frazer made the following statement in 1877,† repeating it two years later:‡ "The porphyry which carries the copper of this region shows no character of igneous action, but occurs in coarse and thin beds, more or less disintegrated, and in some localities reduced almost to the state of kaolin."

Dr. T. Sterry Hunt announced to the American Association for the Advancement of Science in 1876 that he had identified petrosilex or hälleflinta in South Mountain, which he had examined with Dr. Frazer.§ Dr. Hunt's concurrence in 1879 with Dr. Frazer's opinion above cited, and his constant use of the term *bedded petrosilex* sufficiently indicate that he regarded these rocks as sedimentary. He however correctly compares the South Mountain rocks with others in Missouri, the Lake Superior region, eastern Massachusetts, Maine, and New Brunswick, since shown to be volcanic, although he saw in this similarity only evidence of their "Huronian" age.

The nearest approach to a recognition of the South Mountain rocks in Pennsylvania as volcanic was made by Mr. J. F. Blandy, who described the copper-bearing rock in 1879 as *amygdaloid trap*, and correlated it with the similar flows near Lake Superior. The acid felsites however were regarded by Mr. Blandy as slate.‖

In his recent final volume on the Geology of Pennsylvania, Professor Lesley follows in the main Dr. Frazer's classification of the rocks of South Mountain. Although he considers that the sandstone probably represents the "Huronian" of Logan and Murry, he says it is impossible not to compare it with Walcott's Cambrian System. The supposed overlying feldspathic felsite series (orthofelsite of Frazer) Lesley estimates as 6,000 feet in thickness, and everywhere speaks as though he regarded it of sedimentary origin.¶

The cause of the prevailing misconception regarding the volcanic rocks of South Mountain is not difficult to find. Their accompanying accumulations of tuff beds and breccias, and the fact that they are generally cleaved parallel to the

* Report of Progress in the counties of York, Adams, Cumberland and Franklin. Second Geol. Surv. of Penn. CC for 1875. Harrisburg, 1877, p. 285.

† "Copper Ores of Pennsylvania." Polytechnic Review, vol. iii, p. 170, April 28, 1877.

‡ Trans. Am. Inst. Min. Engineers, vol. vii, p. 338, 1879.

§ Proc. Am. Assoc. Adv. Sci., 1876, pp. 211, 212, and Second Geol. Survey of Penn., vol. E, 1878, p. 193.

‖ "The Lake Superior Copper Rocks in Pennsylvania." Trans. Am. Inst. Min. Engineers, vol. vii, p. 331, 1879.

¶ A Summary description of the Geology of Pennsylvania by J. P. Lesley, State Geologist, vol. i, p. 146, 1892.

great structure-planes of the mountain, have all been readily interpreted as indications of stratification and conformity. The cleavage-dip in the sandstone has often been mistaken for bedding, while the thin jointing and slaty structure of the lavas, though a secondary feature, have seemed to geologists not very familiar with recent volcanic rocks, sufficient proof of sedimentary origin.

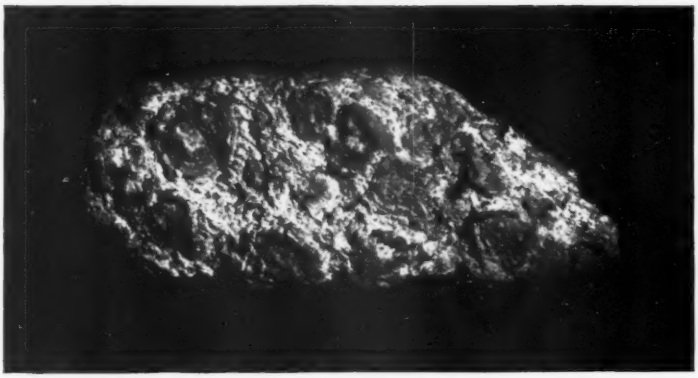
In spite of great age and some alteration, however, the volcanic rocks of South Mountain have preserved all the essential characteristics of our recent rhyolites and basalts in such perfection that the proofs of their real nature are, to the student of comparative petrography, overwhelming, while to all who will candidly examine them they must be at least convincing.

3. *Petrographical Character.*—Approximately 175 square miles of the area of South Mountain is occupied, between Mt. Holly and the head of the Middleton valley, with volcanic rocks. These belong to two types which exhibit sharp contrasts of color, composition and weathering. One type is inclined to tints of red, pink, blue, or purple; is acid in composition; generally porphyritic; and weathers into thin slabs. The other type is almost invariably of a green color; basic in composition; frequently amygdaloidal; and weathers into rough, angular blocks. The rocks of the first type have been called felsite, orthofelsite, porphyry, or petrosilex; those of the second, trap, greenstone, chlorite-slate, or epidote-slate. In view, however, of the perfection with which these rocks have preserved the most characteristic features of their modern equivalents, there is no reason why they should not, like them, be termed *rhyolites* and *basalts*. The insignificance of mere age as a factor in rock nomenclature is now so fully recognized that we may with propriety employ the names of our recent lavas for rocks of any geological horizon, when we can prove beyond doubt their identity.

It is, of course, to be expected that many rocks of intermediate character will be found within this volcanic area. Since the petrographical and chemical study has, however, only begun, and since the contrast above noted is so well defined, the distinction of two types may at present be regarded as sufficient.

a). *The acid rocks, rhyolites.*—The rocks of the acid type occupy somewhat more than two-thirds of the volcanic area of South Mountain—(see map). They occur in dykes and flows forming a body of great thickness; they are accompanied by ashes, tuffs and breccias; they are usually porphyritic, though not always so; they exhibit the characteristics of recent glassy and half-glassy rocks—flow-structures, perlitic structure, litho-

1.



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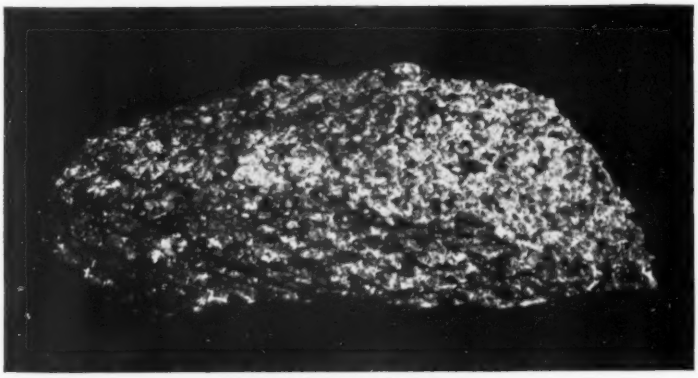


SOUTH MOUNTAIN RHYOLITES.

1.—Lithophysae, Raccoon Creek. 2.—Flowstructure, Raccoon Creek.
3.—Spherulites, North of Tom's Creek.
(All reduced about one-half.)

physae, spherulites (in masses, in layers and in chains), axiolites, pumice, amygdaloids, etc., etc.—in hardly less perfection than the specimens which Professor Iddings has so admirably described from the Yellowstone Park.

These structures are preserved, in spite of the recrystallization of the entire rock-substance into a fine mosaic. They are therefore most apparent in hand specimens, especially when brought out by weathering; or, under the microscope, they are better seen in ordinary than in polarized light, as was the case with the old glass breccia, recently described by the writer from the Sudbury region.*

The following is an analysis of a rhyolite specimen from the Gladhills road, near the Bigham Copper mine, on the north side of Pine Mountain, made by Mr. C. Hanford Henderson of Philadelphia, and published in 1884.† This is a quite typical rhyolite analysis. When compared with analyses of our most recent acid lavas, the iron may seem a little high and the alumina a little low, but on the whole the close agreement is a surprise.

SiO_2	73·62
Al_2O_3	12·22
Fe_2O_3	2·08
FeO	4·03
CaO	0·34
MgO	0·26
Na_2O	3·57
K_2O	2·57
Ign.	0·40
Total	99·09

The macroscopic features of the rhyolite are the best proofs of its true nature, for weathering brings out on the surface of the rock each delicate detail. In this way we discover every characteristic of glassy rocks, though there is no glass now remaining. Plate X, fig. 1, shows in photographic reproduction a specimen five inches long, covered with lithophysæ as perfect as any the Yellowstone can furnish. Their delicate petals are a pale pink, while the base has weathered white. With a lens the radiating and minutely fluted, concentric structure can be traced distinctly. Fig. 4 (p. 488), gives a somewhat diagrammatic idea of this structure.

Plate X, fig. 2, shows the delicate lines of flow-structure as they are displayed on the weathered surface of a specimen which

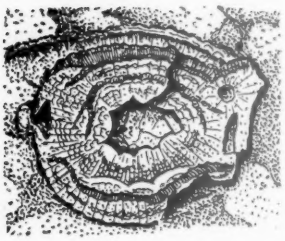
* Bull. Geol. Soc. Am, vol. ii, p. 138, 1891. Ann. Rept. Geol Surv. Can. for 1889–90, F, p. 75, 1891.

† "The Copper Deposits of South Mountain," by C. H. Henderson. Trans. Am. Inst. Mining Engineers, vol. xii, p. 90.

in its interior is a homogeneous, dark purple felsite. On other specimens these flow lines are even more sinuous. This specimen was merely selected from a great variety because it appeared well-fitted for reproduction.

At some localities the rhyolite is crowded with spherulites. Plate X, fig. 3, represents a large specimen found north of the junction of Copper run with Tom's Creek. Here the spherulites make most of the mass and have no regular arrangement. They have the size of large peas. In other cases the spherulites are of smaller size and more sparsely distributed. They are then not infrequently arranged in layers as described by Iddings in the Yellowstone obsidian.* One specimen from Raccoon Creek (No. 143) shows small but very perfect, grey spherulites distributed, singly, in layers or in large aggregates through a black base which was once probably obsidian. In appearance it is not unlike the well known specimens from the Lipari Islands.

4.



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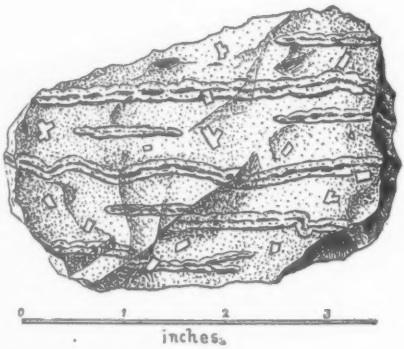

Fig. 4. Structure of a lithophysa brought out by weathering—natural size—No. 129, from Raccoon Creek.

Fig. 5. Hand specimen showing chains of spherulites—No. 78, from near Snowy Mountain.

Another very common arrangement of spherulites is shown in fig. 5. Here they occur in single layers, which, in cross-section, appear like chains, bent more or less out of their normal horizontal position by the flow-motion of the magma. The individuality of these spherulites is preserved, though they are so merged into one another that they approach the axiolitic structure. This structure is so frequent that it has doubtless helped confirm the idea that the felsite and porphyries were

*Obsidian Cliff, 7th Ann. Rept. U. S. Geol. Surv., p. 276, Plate xviii, 1888.

stratified. It seems to be quite independent of the presence or absence of phenocrysts in the rock.

Still another characteristic, which the South Mountain rhyolites possess in common with many recent lavas, is what we may call the *eutaxitic* structure.* This consists of the close intermingling of two portions of the magma which, on account of some slight differences in chemical composition or hydration, show a marked contrast in color. The two portions may be, for instance, black and white, pink and blue, or red and gray. They mingle so as to produce in some cases an irregular mottling; in others a complex series of interlacing bands which bring out the flow-structure in a striking manner. Specimen No. 145, from Raccoon Creek, shows small black areas resembling shreds of glass, imbedded in a pink base which, on a weathered surface, appears snow-white.

Amygdaloidal structure, representing old vesicles more or less elongated by motion in the viscous mass, is much less common in the acid, than in the basic rocks. Fine examples of it were, however, found at the Bigham Copper mine; along Raccoon Creek and at the eastern end of the Jack's Mountain tunnel (Nos. 20, 147 and 7). As a microscopic feature this vesicular structure is still more common, (see fig. 6). Perlitic parting, so characteristic of glassy rocks, may be detected macroscopically in many felsite specimens.

The microscopical characters of the South Mountain rhyolites are far too varied to be described in a brief paper like the present. It must suffice to say that, in spite of the recrystallization of the substance, we still find in great perfection all the essential features of the most recent acid lavas. Corroded and skeleton phenocrysts of quartz, micropegmatitic intergrowths of quartz in feldspar phenocrysts,† and phenocrysts broken by the flow movement. In the groundmass we find spherulitic tufts, axiolites, elongated vesicles filled with quartz, trichites and globulites in great variety, which bring out each detail of flow-structure. All the particulars of microscopic structure call for extended study and description. For the present purpose, however, which is merely to establish the character of these rocks, what has been said must suffice.

In mineralogical composition the South Mountain rhyolites are quite uniform. When phenocrysts are present, the most abundant are alkali feldspar.. Quartz in rounded bipyramids is always to be found with the feldspar under the microscope, although it is not so often apparent to the unaided eye. In only a single instance (No. 257D, from the head of Miney

* Fritsch and Reiss: Tenerife, p. 414, 1868. Rosenbusch: Die Massigen Gesteine, 2d Ed., p. 625.

† J. P. Iddings: loc. cit., p. 274 and Plate xv.

run) has any ferro-magnesian constituent as yet been detected. In this case biotite is abundant as an original mineral. The groundmass of the rhyolites is for the most part a quartz-feldspar mosaic of varying grain, much of which is the result of devitrification and recrystallization, though some of it is also probably original microgranite.

6.

Fig. 6.—Axiolitic and vesicular flow structures. No. 77 from near Snowy Mtn., mag. 5 diameters.

7.

Fig. 7.—Flow structure. No. 61, South of Willow Grove, Pa., mag. 5 diameters.

Attention has been called by Tyson,* Hunt† and Frazer‡ to the beauty of the South Mountain porphyries, and to the fact that they are so susceptible of a high polish as to make them valuable for decorative purposes. Many of them closely resemble the famous *porfido rosso antico* of Egypt, which is largely used by the lapidaries of Rome.

b) *The basic rocks, basalts.*—The basic lavas of South Mountain occupy an area about one-half as large as that covered by the acid ones. They reach their maximum development near the State line, where, along the southern edge of Pennsylvania and for a considerable distance into Maryland, they form the entire width of the volcanic belt. North and south of this main body, the basic rocks or greenstones are everywhere met with as narrow bands intersecting the rhyolites and following the general trend of the mountain. These bands differ much in their width, but seem to be most developed along the eastern flanks of Green Ridge and Piney Mountain.

* First Annual Report, 1860. Appendix, p. 3.

† Proc. Am. Assoc. Adv. Science, 1876, p. 212 (compares them with the Elfdalen porphyries).

‡ Second Geol. Survey of Penn., vol. CC, p. 285.

These rocks have been more generally sheared into slates than the acid lavas. The chemical alteration which has gone on in them is also in general greater. Still large masses of the basic rocks have been but little altered and remain quite massive. These, which are locally known as "copper rock," are the only members of the volcanic series whose igneous origin has been heretofore conceded. They are for the most part very fine grained, vesicular flows, whose original structure is still so well preserved that they may with propriety be called basalts.

The following analysis, also by Mr. C. H. Henderson, of a massive greenstone from the Bechtel copper shaft, Russel mine, is published by Dr. Frazer.* This is a normal basalt analysis, indicating as little chemical change in the basic rocks as the one given above does in the acid rocks.

SiO_2	41·280
Al_2O_3	18·480
Fe_2O_3	9·440
FeO	8·200
CaO	7·040
MgO	7·486
Na_2O	3·523
K_2O	2·208
Ign.	2·740
Total	100·397

Basic volcanic rocks never exhibit so great a variety of structure forms as characterize the more acid rhyolites. The South Mountain basalts are usually homogeneous, dark to pale green masses which rarely show any microscopical phenocrysts and whose most constant feature is amygdaloidal structure. These cavities vary greatly in size, shape, and abundance. They are often elongated by flow-motion in the lava and are now filled with a number of secondary minerals, the most abundant of which are epidote, chlorite, quartz, and zeolites. Traces of original glass or spherulitic structure (variolite) have not yet been detected in the basalts.

The mineral constituents of basic rocks are more subject to alteration than those of acid ones. It could not be expected that basalts so ancient and so vesicular as those of South Mountain would escape all change, but it is a surprise in many cases that this change has been so small. The ferro-magnesian constituents have always altered to epidote, chlorite or serpentine, but the structure is frequently preserved in its minutest

* "Hypothesis of the structure of the Copper belt of South Mountain," Trans. Am. Inst. Min. Engineers, vol. xii, p. 82, 1883–4.

detail. Under the microscope the ophitic network of feldspar laths is still fresh, and the delicate twinning as distinct as in a recent lava. The form of the basaltic magnetite, of the olivine phenocrysts, and of the interstitial pyroxene is also plainly visible, while the arrangement of the feldspar microliths among the oval vesicles clearly indicates the motion of the still viscous mass.

Fig. 8 gives two types of the basaltic structure. The one on the left shows skeleton phenocrysts of olivine and a fine grained, ophitic groundmass.

8.

Fig. 8, mag. 5 diameters.

Left half.—Basalt with skeleton olivines, ophitic structure, fresh feldspar. Amygdules filled with quartz and chlorite. Railroad, east of Monterey. Pa.

Right half.—Somewhat coarser grained basalt. Amygdules filled with zeolites and quartz grains. Railroad, east of Monterey, Pa.

Both have large amygdules which are either oval or of irregular shape, and filled with different minerals.

c) *Pyroclastic deposits, tuffs and breccias.*—As is generally the case with large accumulations of surface eruptions, the South Mountain lavas are accompanied by extensive deposits of pyroclastic material. This includes coarse flow- and tuff-breccias, pumiceous bombs, and banded accumulations of fine volcanic ash. Like the massive rocks, this fragmental matter is both acid and basic in composition.

The most striking and important area of acid tuffs covers about a square mile in the Buchanan valley, at the eastern base of Piney Mountain, two miles north of the Chambersburg turnpike. Here the rock is a breccia whose component fragments vary from two or three feet in diameter to the finest ash. All sizes, shapes, and colors are heterogeneously mingled,

and the result bears a superficial resemblance to the well-known triassic breccia ("Potomac marble," "calico rock") of the Frederick valley. The material in this case, instead of being limestone, is entirely rhyolite, and exhibits remarkable variety of structures and colors. Both flow- and tuff-breccias occur here, while a portion of the mass has been sheared into a quite fissile slate. Similar acid tuffs, though of less striking appearance, occur at many other points (Raccoon Creek, Monterey, old Furnace road, etc.), and will doubtless continue to be discovered as the examination of the region proceeds.

Fragmental deposits consisting wholly of basaltic material abound along the Western Maryland railroad near Monterey, and farther south. The finer cementing material is in these almost always altered to epidote. It is also not uncommon to find coarse breccias consisting of both the acid and basic types of rock, but a careful search has thus far failed to discover any fragments of sandstone in these pyroclastic beds.

4. *Geological occurrence and relations to the Sandstone.*— No evidence is necessary, beyond the petrographical characters above described, to establish the igneous and volcanic nature of the South Mountain rocks. Additional evidence of a purely geological kind is not, however, wanting. The vicissitudes through which these ancient rocks have passed, and their present inadequate exposure, tend to obscure their original relationships. Nevertheless dykes may be seen at various points, especially at the western end of the railroad tunnel on Jack's Mountain, where an amygdaloidal red felsite cuts the massive and schistose greenstones. Further exploration will doubtless bring to light many similar occurrences. Successive flows are not now easy to separate, but the amygdaloidal and fluidal structure of the rocks indicates that they must have been extruded in this form.

The age of the South Mountain volcanics and their relations to the sandstone in which Mr. Walcott has recently identified the lower Cambrian fauna, are points of great interest. The hypothesis of the Pennsylvania geologists that the greenstones and felsites lie above the sandstone is evidently incorrect. It may, however, be regarded as an open question whether the volcanic rocks represent a much older horizon, which was already eroded before the sandstone was deposited, or whether they were, in part at least, contemporaneous with the sandstones.

The entire absence of sandstone as inclusions in the lavas, as well as in all the accumulations of pyroclastic material; the observations of Keith, Geiger* and Walcott,† that the

* Bull. Geol. Soc. America, vol. ii, p. 155; plates 4 and 5.

† This number of this Journal.

sandstone lies flat or in synclinals; and the sections made by Miss Bascom across Monterey Peak, Pine Mountain, Jack's Mountain, and Haycock near Monterey, all indicate that the sandstone is altogether above the volcanic rocks, and that it has been only sporadically left by erosion on the east side of the mountain in Pennsylvania. In Maryland the volcanic rocks are flanked both on the east and west by sandstone (see map). No alternations of relatively thin beds of sandstone and lava have thus far been observed. The contacts of the sandstone above the porphyry on the old tapeworm railroad southwest of Maria's Furnace, and above the greenstone in the Jack's Mountain railroad tunnel are both admirable exposures, but both seem to be thrust-planes and are not contacts of original deposition.

The South Mountain volcanic rocks therefore become, not merely in their petrographical character and richness in metallic copper, but also in their stratigraphical position, comparable with the Keewenawan or Nipigon series of Lake Superior.

5. *Chemical Alteration and Metamorphism.* — Extensive chemical changes, involving devitrification and the formation of new minerals, have gone on in all the volcanic rocks of South Mountain without destroying the original structures. In other cases, where there has been movement and shearing, the same rocks have lost both their original minerals and structures by a process of complete metamorphism. The results are more or less perfectly foliated schists and slates, whose origin can be positively traced to the volcanic rocks, and whose present form can be shown to depend upon the intensity of the dislocation to which they have been subjected.

The chemical changes which have not affected the massive character of the rocks consist of the formation of new minerals to accord with the altered physical conditions. These have, as a rule, merely replaced the former minerals so as to leave the original structure of the rock intact. In the basic rocks the new minerals are epidote, fibrous green hornblende, chlorite, serpentine, iron oxide, and, to less extent, calcite and quartz. Of these by far the most important is epidote. Indeed the conditions for the formation of this substance must have been exceptionally favorable, as it has everywhere been produced in great abundance. Some of the finer material, like volcanic ash or breccia cement, is wholly altered to this mineral. It is also the most common filling of the amygdules.

In the acid rocks there has been a complete recrystallization of all glass into a fine quartz-feldspar mosaic, which, however, still exhibits the original structures. The conditions favorable to epidote formation are manifest in these rocks in the presence of large amounts of the manganese epidote (piedmontite).

This rare mineral is so abundant and occurs in such interesting relations that it will soon be made the subject of a special communication.

The manner in which these compact, fine-grained rocks have been reduced along lines of shearing into fissile slates is most instructive. This is accompanied by the abundant production of sericite in the acid, and of chlorite in the basic rocks, while the phenocrysts and all original structures are obliterated. Amygdules, where present, usually remain as flattened spots, either lighter or darker than the rock. Several suites of specimens have been collected to illustrate this process, but the account of its details must be reserved for a future paper.

That the large area of fissile, pale green schists occurring between Pine Grove Furnace and Laurel Forge consists of sheared felsite may be seen from the following analysis, made for commercial purposes by A. S. McCreath. This rock, which is locally known as "soapstone," is extensively used at Pine Grove Furnace in the manufacture of brick. Its alkalies were not determined.

SiO_2	74·970
Al_2O_3	13·860
FeO	2·700
CaO	0·220
MgO	1·230
Alkalies	?
Ign.	2·058
Total	95·038

6. *Comparison with other regions.*—The comparative rarity of very ancient volcanic rocks in America as compared with Great Britain* and other parts of Europe is doubtless due to their not having been recognized, rather than to their actual absence. The opinions entertained by Hunt of rocks like those of South Mountain have greatly retarded, in this country, the appreciation of their true character. Still they are well known on Lake Superior and in Missouri through the writings of Irving† and E. Haworth;‡ Wadsworth§ and Diller‖ have described them in eastern Massachusetts, Shaler¶ in Maine, and the northern continuation of this same belt has been made

* Sir A. Geikie: Anniversary Address, Quart. Jour. Geol. Soc, vols. xlvii and xlviii, 1891–1892.

† Monographs U. S. Geol. Survey, v, 1883; and Bulletin, No. 62, 1890.

‡ Am. Geologist, vol. i, p. 280, 1888, and Bull. Missouri Geol. Survey, No. 5.

§ Bull. Mus. Compar. Zool Cambridge, vol. v, No. 13, p. 282.

‖ Ibid., vol. vii. No. 2, 1881.

¶ This Journal (III), vol. xxxii, p. 40, 1886. Ann. Rep. U. S Geol. Surv., vol. viii, p. 1043, 1889.

known by the Canadian geologists, Bailey, Matthew and Ells, in New Brunswick.* Bell has also recently described similar rocks in the Sudbury region.†

Similar areas are easily recognizable in Canada and Maine from the writings of Hunt, Jackson and Hitchcock, in spite of the fact that they are not properly interpreted. Volcanic rocks have not before been clearly identified in the Appalachians, but if attention is called to them they will doubtless be recognized at many other points.

Petrographical Laboratory,
Johns Hopkins University, Nov. 1, 1892.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Temperature of Steam from Boiling Salt-solutions.* Considerable diversity of opinion exists on the question of the temperature of the vapor arising from boiling salt-solutions. Certain observers, as Faraday, Wüllner and Magnus, maintain that this temperature is the same as that of the solution, while others, as Rudberg and Müller, hold the opinion that it is practically the same as that arising from water, boiling under the same pressure. In order to settle the question Sakurai has made a series of experiments in which certain sources of error incident to previous methods of investigation were avoided. His apparatus consisted of a long necked flask containing the solution, through the stopper of which two thermometers passed, one with its bulb in the solution the other with its bulb in the vapor above it. The neck of this flask was surrounded with a jacket, into which vapor could be passed from a boiler, and which was connected with a condenser. A third thermometer indicated the temperature in the jacket. Through a tubulure in the side of the flask, steam was blown in order to supply sufficient vapor to maintain the temperature in the neck, the excess of vapor passing off through a tube in the stopper. The solution to be examined was placed in the flask without soiling the neck, the stopper was inserted, a solution of acetic acid boiling at a slightly lower temperature than the solution was placed in the boiler and made to boil, and the gas was lighted under the flask. When the solution was heated to boiling, steam was admitted through the lateral tubulure and the whole being in equilibrium, the temperature of the thermometer was read. With a dilute solution of calcium chloride, the temperature of the solution varied from 112·5° to 113·3°, that of the jacket from 110·8° to 111·9° and that of the vapor from 111·2° to

* Ann. Rep. Can. Geol. Surv., 1877–8 DD, and 1879–80 D.
† Ibid., for 1889–90 F, 1891.

113·3°; the difference between the temperature of the vapor and that of the solution, in eight experiments, being as much as one degree in a single case only. Solutions of potassium nitrate and of sodium nitrate gave similar results. "The experiments above described prove beyond any possible doubt," says the author, "that the temperature of the steam escaping from a boiling salt-solution is exactly the same as that of the solution. This I believe is the first occasion on which the above important fact has been experimentally established."—*J. Chem. Soc.*, lxi, 495, June, 1892. G. F. B.

2. *On the Allotropism of Amorphous Carbon.*—A graphitite has been investigated by Luzi, obtained from the chalk at Wunsiedel in the Fichtelgebirge, which was pronounced by both Fuchs and by Sandberger to be amorphous carbon, the latter considering it identical with the graphitoid or schungite of Lauer and Inostranzeff. A similar graphitite, occurring at Storgård in Finnland, has also been examined by Luzi. It occurs in the form of dark gray nodules which mark paper like graphite, have a conchoidal fracture but no cleavage. Its density is 2·255–2·26 at 17·5°, and on combustion in oxygen it leaves 0·67 per cent of a light yellow ash. The Wunsiedel mineral has a density of 2·207, and is also entirely amorphous. It is free from hydrogen and nitrogen, and on oxidation with potassium chlorate and nitric acid, gives, after five successive treatments, an orange-yellow substance, becoming brown on drying and insoluble in water and nitric acid. On heating, it is decomposed with a hissing sound, and glows, leaving behind a black powder. Under the microscope it appears to consist of minute irregularly rounded plates, which are doubly refracting. On analysis it gave 57·99 per cent of carbon, 1·93 per cent of hydrogen and 46·08 per cent of oxygen. Since ordinary amorphous carbon is completely oxidized by treatment with potassium chlorate and nitric acid, as is also schungite, and since graphite is converted into graphitic oxide by this treatment, the author considers this a new variety of amorphous carbon resembling graphite in the products of its oxidation. Indeed it appears to resemble closely graphitite produced in arc-light carbons, the oxidation-product of which gave Berthelot C 51·95, H 1·55 and O 46·50. This product the author calls graphititic oxide.—*Ber. Berl. Chem. Ges.*, xxv, 1378, April, 1892. G. F. B.

3. *On amorphous Boron.*—Moissan has prepared the so-called amorphous boron by the various methods described and has analyzed the products. By the method of Gay Lussac and Thenard, acting on boric oxide with potassium, using a copper tube, the product contained 44·1 per cent of boron. By acting on boric oxide with sodium in presence of sodium chloride, the method of Deville and Wöhler, a product containing 62·50 per cent of boron was obtained. By acting on potassium borofluoride with potassium, method of Berzelius, the product contained 51·15 of boron. On extracting the second product with boiling hydrochloric acid, the quantity of boron was raised to 71·97 per cent; extraction

with water lowering it to 32·38 per cent. In consequence the author first attempted to prepare boron electrolytically. When a current of 35 amperes is passed through boric oxide mixed with one fifth of its mass of sodium borate and heated to 1200°, boron is set free but at once burns to oxide. He then tried reduction by means of magnesium, mixing 70 grams of finely powdered magnesium with 210 grams of recently fused boric oxide, and heating the mixture to bright redness in a clay crucible. After the action was over, the mass was treated with water acidulated with hydrochloric acid, then with boiling strong hydrochloric acid, then with alcoholic potash and finally with hydrofluoric acid. The product was a light maroon powder, containing 94 or 95 per cent of boron. If this be fused with 50 times its weight of boric oxide and again treated with magnesium a product is obtained containing 98·3 per cent of boron. And if the reduction be effected in a crucible brasqued with titanic oxide and carbon, the percentage of boron may reach 99·2.—*C. R.*, cxiv, 319, 392; *J. Chem. Soc.*, lxii, 681, 682, June, 1892. G. F. B.

4. *On the Atomic Mass of Boron.*—Abrahall has determined in Dixon's laboratory the atomic mass of boron by titrating boron bromide by means of silver nitrate. The mean of five accordant determinations gave 10·825.—*J. Chem. Soc.*, lxi, 650, Aug., 1892. G. F. B.

5. *Absorption power of metals for the Energy of Electrical waves.*—Hertz concluded from his experiments that the production of resonance and the period of oscillation in resonators are not affected by the specific resistance or the magnetic properties of the secondary conductor. Bjerknes of the University of Christiana has examined this subject using an electrometer and finds that copper, brass, german silver, platinum, nickel and iron show different absorptive powers. The rate of absorption increases with the resistance and the magnetization of the metal. Iron and nickel showed a marked damping effect. Their magnetization however could be reversed one hundred million times per second. Bjernkes makes no reference to earlier papers of John Trowbridge and also of Professor Thomson of Cambridge, England, on this subject. *Ann. der Physik und Chemie*, 1892, No. 9, pp. 69–76. J. T.

6. *Electrical Oscillations.*—M. Zehnder exhibits to a large audience Hertz's oscillations by placing the conducting rods in the focal line of a concave mirror. These rods are connected with a Geissler tube within which the ends are placed very close together so that a general luminosity is produced inside the tube. The effects are augmented by a species of relay. On either side of the terminals of the resonator are two other terminals from a circuit of 600 Planté cells of small size, which are regulated so that the current is just able to pass between the terminals. When the resonator responds to the electric oscillations the discharge from the cells is augmented. It is also possible to work with another Ruhmkorff coil instead of with the secondary battery. *Ann. der Physik und Chemie*, 1892, No. 9, pp. 77–92. J. T.

7. *On Joints in Magnetic Circuits.*—Prof. EWING shows the great effect of joints in reducing the residual magnetism of iron. The division of a ring 30^{cm} long into two half rings abutting against each other with the smoothest possible joints has the effect of reducing the residual magnetism from 9,000 to 6,000. "A similar reduction occurs in magnetic tests of bars when these are made to form part of a magnetic circuit by the addition of a marine iron yoke."—*Phil. Mag.*, Oct., 1892, pp. 320–326. J. T.

8. *Measurement of high temperatures.*—LUDWIG HOLBORN and WILLY WIEN discuss the electrical methods of measuring high temperatures and give results obtained by the use of a thermo-element of platinum and platinum-rhodium. This method appears to be preferable to Siemens's method of observing change in electrical resistance. The authors obtain concordant results for the melting point of gold, silver and copper.—*Ann. der Physik und Chemie*, 1892, No. 9, pp. 107–134. J. T.

9. *Color Photography.*—LIPPMANN by the aid of a very sensitive bromide of silver albumen plate, made orthochromatic by a solution of azalin and cyanine has succeeded in photographing the solar spectrum. Also a colored church window, a parrot, and other colored objects. The time of exposure with sunlight and the electric light varied from five to ten minutes. With diffuse light an exposure of several hours was necessary.—*Comptes Rendus*, cxiv, p. 961, 962, 1892. J. T.

10. *Electrical Resistance of Metals at Low Temperatures.*—Prof. DEWAR and Prof. FLEMING have studied the electrical resistance of metals at the temperature of boiling oxygen, −197° C., and find an enormous decrease in the specific resistance of perfectly pure metals. Pure iron at −197° C. has $\frac{1}{23}$ of its resistance at 100° C. and pure copper $\frac{1}{11}$. The smallest impurity affects the results to a remarkable degree. A carbon filament such as is used in an incandescent lamp continually increased in resistance as the temperature was lowered. Carbon thus acts just the reverse of metals. Iron and nickel change most. Pure iron at the temperature of boiling oxygen, −197° C., conducts better than electrolytic copper at ordinary temperatures.—*Phil. Mag.*, Oct., 1892, pp. 326–337. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Les Régions Invisibles du Globe et des Espaces célestes: Eaux Souterraines, Tremblements de Terre, Météorites;* par A. DAUBRÉE, Membre de l' Institut. 240 pp. 8vo. 1892.—This volume is one of the series entitled "Bibliothèque Scientifique Internationale," published at Paris under the direction of Ém. Alglave. Prof. Daubrée has here brought together some of his very valuable papers illustrating geological principles by experimental researches. The papers included are the following: I. The work of subterranean waters at the present time; II. The part they have taken as mineralizers during geological time; III. Earth-

quakes; IV. The geological work of subterranean gases; V. Meteorites, and the constitution of the globe. It is greatly to the advantage of the science that Prof. Daubrée has made his important memoirs so conveniently accessible to those interested in the subject. This second edition contains several new figures.

2. *The Pleistocene History of Northeastern Iowa*; by W. J. McGee; pages 189 to 577 of the eleventh annual report of the director of the U. S. Geological Survey for 1889–90. A notice of this very complete memoir on northeastern Iowa is deferred to another number.

3. *Geological Survey of Iowa.*—A bill for a new geological survey of Iowa passed the legislature of the State last winter. The appointments made for the Survey are Prof. S. Calvin, Geologist, Charles R. Keyes, Assistant Geologist, and G. E. Patrick, Chemist.

4. *Tiefencontacte an den intrusiven Diabasen von New Jersey.* A. Andreae and A. Osann. (Verhandlungen des Naturhist.-Med. Vereins zu Heidelberg).—The locality which was personally studied by the writers is that at Jersey City and the diabase that of the well known Palisades. The contact of this diabase with the Newark shales is remarkable in that in extent and character it resembles that of the coarse granular abyssal rocks and not the ordinary diabase contact. The shales and arkose are completely changed to silicate hornstones, of which several varieties, one rich in tourmaline, are described. Thus the opinion that this diabase is intrusive receives strong support. L. V. P.

5. *Eleolite-Syenite of Litchfield, Me. and Red Hill, N. H.* W. S. Bayley (Bull. Geolog. Soc. Am., vol. iii, pp. 231–252).—This paper gives a careful and minute petrographical and chemical study of two varieties of eleolite-syenite. The occurrence at Red Hill, N. H., had been previously described by Hawes in his Lithology of New Hampshire as a hornblende syenite, the nephelite having been overlooked. It consists of augite, hornblende, biotite, sodalite, nephelite, albite, orthoclase and sphene. The study was made on hand specimens and nothing is yet known of its geological occurrence and connections. The same may be said of the rock from Litchfield, search in the field not yet having shown the source of the bowlders in which it occurs. This latter is shown to be a new variety of eleolite syenite in that the alkali feldspar is chiefly albite, not orthoclase. Hence regarding the albite as the most acid of the plagioclases, by a strict interpretation of Rosenbusch's system of classification, the rock would fall among the theralites and to avoid this difficulty the author proposes to distinguish the variety by the name of "Litchfieldite." This shows the rather unfortunate result of attempting to classify rocks by set schemes as if they were species. If we accept the conception held by most petrographers that eleolite-syenite is an alkali magma—rich in alumina, moderate in amount of silica, poor in ferro-magnesia and lime—crystallizing into a granular rock composed essentially of nephelite and alkali feldspar with

one or more members of the amphibole, augite or mica families present, and not according to the crystallographic nature of the essential feldspar, the name proposed seems hardly necessary.

L. V. P.

6. *The Gems and Precious Stones of North America;* by GEORGE F. KUNZ.—An Appendix to this fine work, making pages 337–367, has recently been issued. It gives much interesting matter, supplementary to the main volume, chiefly that which mineralogical investigation has brought out in the past two years.

7. *Muciferous System of Laminariaceæ*, by GUIGNARD (Annales des Sciences Naturelles, 15, 1).—This study proves that certain genera of *Laminariaceæ*, such as *Lessonia* and *Alaria*, can comprise species which have no muciferous canals, while others possess them. We therefore must conclude that their presence or absence cannot offer any specific character. G. L. G.

8. *Researches on Multiple Buds*, by W. RUSSELL (Annales des Sciences Naturelles).—The principal conclusions which these researches have led the author to are:

(1) Lateral buds can be produced at the expense of the constituent parts of the foliar axil, either at the expense of the stem alone, or more rarely, that of the leaf. In the inflorescence of the Linden, Cactaceæ, and so on, their appearance can take place upon the summit at the same time as that of the axillary leaf.

(2) Every bud has at the commencement a double growth,—a proper growth, or one peculiar to itself, and a growth in common with the organs which have formed it. The latter is in general much more rapid than the former, at least at the outset.

(3) The majority of leafy buds, and numerous flower-buds, can send out branches at their base.

(4) These buds are the origin of successive ramifications which accompany the bud of the first generation, and sometimes these possess no axillary leaves at all.

(5) These successive ramifications, which are ordinarily designated as accessory buds or multiple buds, behave at the outset just as axillary buds themselves.

(6) The disposition of these buds always obeys the laws of phyllotaxy.

(7) The basal ramifications have a well-defined biological rôle. It is from these that many thorns and tendrils are produced, or modifications of inflorescence.

(8) In the majority of cases these buds remain in the state of dormant buds, and are the origin of distortions which appear under certain circumstances in woody plants. Sometimes upon annuals they play the rôle of hibernating buds, and permit the plant to grow from one year to another. They can develop in the same year that they form, or in the following year, coincidental with the bud of the first generation.

(9) We can show experimentally that the formation of these buds can continue throughout the whole life of the plant. This is well illustrated by *Convolvulus*, for example.

The principal results of these researches can be condensed into a single statement: the law of the unity of the axillary bud has absolutely no exception. G. L. G.

9. *Artificial intracellular Crystallization;* E. BELZUNG.—The author has shown conclusively that within the cell it is possible to produce artificial crystals of considerable size. His résumé, stated at considerable length by him, is condensed in the following shorter statement:

(1) All these crystallizations can be produced by the simple means of placing living tissues in pure glycerine. This reagent produces an exosmosis more rapid than that of the crystallizable substance dissolved in the water. From this process the sap is carried to the point of saturation and must undergo an intracellular precipitation.

(2) The most abundant principles which are contained in young plants which he has studied are asparagine, leucine, and neutral sulphate of potassium. The two amides crystallize in the cells simultaneously with the greatest facility. In *Lupinus luteus*, asparagine, tyrosine, and sulphate of calcium are produced. The gypsum crystallizes in the tissues, for Cicer, xanthine and calcium sulphate. Xanthine has been hitherto unknown as a product of the normal activity of the plant. It crystallizes clearly in the cells, in very delicate filamentous forms. In *Cucurbita pepo*, asparagine and potassium nitrate, can be very easily made to crystallize in all these cases.

(3) The metamorphosis of protein and saline matters under these conditions is almost exactly like that which takes place in the ripening of a seed, so that we have really artificial aleurone grains formed, much as in a ripened seed.

(4) What is the mechanism of the formation of these different products? Certain of the amides are produced from albuminoid matters by dilute acids or alkalies, as a consequence of the action of particular ferments, diastatic or peptonizing. So far as the mineral products, the nitrates and sulphates, are concerned, little can be said positively. The nitrates of germination, for example, are comparable with those salts of the same composition which result from bacterial fermentation of ammoniacal compounds, and the same remark applies to the sulphates of germination. G. L. G.

10. *On the Aeration of Solid Tissues;* HENRI DEVAUX.—(1) The internal atmosphere of all solid tissues contains a notable proportion of oxygen, in certain cases pretty nearly that which exists in pure air.

(2) The proportion of carbonic acid is in general feeble.

(3) The proportion of nitrogen is often different from that which exists in pure air, sometimes less, often more.

(4) The total pressure of the internal atmosphere differs from that of the exterior air, sometimes positively, more often negatively, and its ratio is always inverse to the proportion of nitrogen.

(5) We may consider tubers, tubercles, fleshy fruits, and most solid organs as formed of a mass very porous in its character,

which is enveloped by a thin and porous membrane, less permeable than itself. Sometimes this has no normal pores, for instance, in the apple, the orange.

(6) It is probable that a gas which traverses the envelope can penetrate to the deepest part of the tissue.

(7) The gas passes through the external envelope of solid masses, sometimes in the free state, and sometimes dissolved.

(8) The changes which are produced at the surface depend on the permeability and the porosity of the peridermic membrane.

(9) Oxygen tends to enter especially by the pores, while carbonic acid escapes from the whole surface of the membrane. There exists a veritable circulation of these gases, but the circulation is only partial in the majority of instances.

(10) Humidity acts in a very variable manner on the composition of the internal atmosphere, sometimes increasing permeability, sometimes diminishing it.

(11) Slow or rapid drying diminishes permeability and causes a greater and greater accumulation of carbonic acid.

(12) It is to these variations in the proportions of oxygen and carbonic acid in the internal atmosphere that we must attribute the different values of pressure in the internal atmosphere.

(13) According as the total pressure is stronger or weaker in the internal atmosphere, there is produced across the superficial pores an inward or an outward current. This gaseous current is purely mechanical, and can be regarded as a third series of exchanges.

(14) Nitrogen is passively held in this gaseous current.

(15) When the gas acquires a constant difference of pressure, in spite of the constant sweeping hither and thither, we must believe that the current is produced in some other way than by diffusion. A constant circulation of nitrogen exists in the aërial parts of plants, but the circulation is purely passive.

(16) Temperature increases or diminishes the intensity of respiration, and this modifies the composition of the internal atmosphere.

(17) Light acts wherever green matter exists, sometimes through chlorophylline assimilation, and sometimes by the withdrawal of water, thus influencing the permeability of the membranes.

The mechanism of exchange can be summed up in the following conclusion: Gaseous exchanges of all solid organs hitherto studied are produced in three different ways, which ordinarily coexist, but which act with a variable intensity. These are, Effusion; Dialysis; and a purely mechanical passage of a gaseous current.

Effusion. Diffusion of free gas across the pores of an envelope under the influence of differences of pressure proper to each gas.

Dialysis. Diffusion of gas, dissolved, across the membrane under the same influence.

Gaseous current. General displacement of the total mass of the mixed gases across the pores of the envelope under the influence of the difference of total pressure which exists between the interior and the exterior. G. L. G.

11. *Bibliotheca Zoologica*, II.—This valuable and exhaustive work, under the editorship of Dr. O. Taschenberg, giving the titles of works and articles on Zoology which appeared between 1861–1880, has reached its 10th Lieferung. This includes the last of the Mollusca and beginning of the Vertebrates, covering signatures 361 to 400, or pp. 2929 to 3248.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—At the meeting of the National Academy held in Baltimore, Nov. 1 to 4, 1892, the following papers were presented:

G. K. Gilbert: The Evolution of the Moon.

T. C. Mendenhall: On the Observations for Latitude at Rockville. Md. On the Latitude Observations at Honolulu. The Use of Planes and Knife-edges in Pendulums.

Thomas B. Osborne: Crystallized Vegetable Proteids. Proteids of the Flaxseed.

H. A. Rowland: A Spectroscopic Analysis of the Rare Earths. A Table of Standard Wave-lengths. On the Motion of a Sphere in a viscous Fluid.

G. H. Williams: Volcanic Rocks of South Mountain in Pennsylvania and Maryland.

Ira Remsen: On Some Curious Double Halides. Study of the Action of Light on acids in Solutions containing a Salt of Uranium.

C. Barus: On Isothermals and Isometrics of Viscosity.

W. K. Brooks: Significance of the Follicle of Salpa. Biological Relations of the oldest Fossils.

E. D. Cope: On the Vertebrate Fauna of the Blanco Epoch.

S. C. Chandler: On the Motion of the Earth's Pole.

C. S. Hastings: Recent Improvements in Astronomical Telescope.

George E. Hale: Exhibition of Photographs illustrating new methods and results in Solar Physics.

George E. Squier and Frank A. Wolff, Jr.: Some effects of Magnetism on Chemical Action.

Volume V of the Memoirs of the Academy, which has just appeared, is a large quarto of about 600 pages with many plates. The following are the papers it contains: On energy and vision by S. P. Langley; Contributions to Meteorology by Elias Loomis; Report of studies of atmospheric Electricity by T. C. Mendenhall; Embryology and metamorphosis of the Macroura by W. K. Brooks and F. H. Herrick; Application of interference methods to astronomical measurements by A. A. Michelson.

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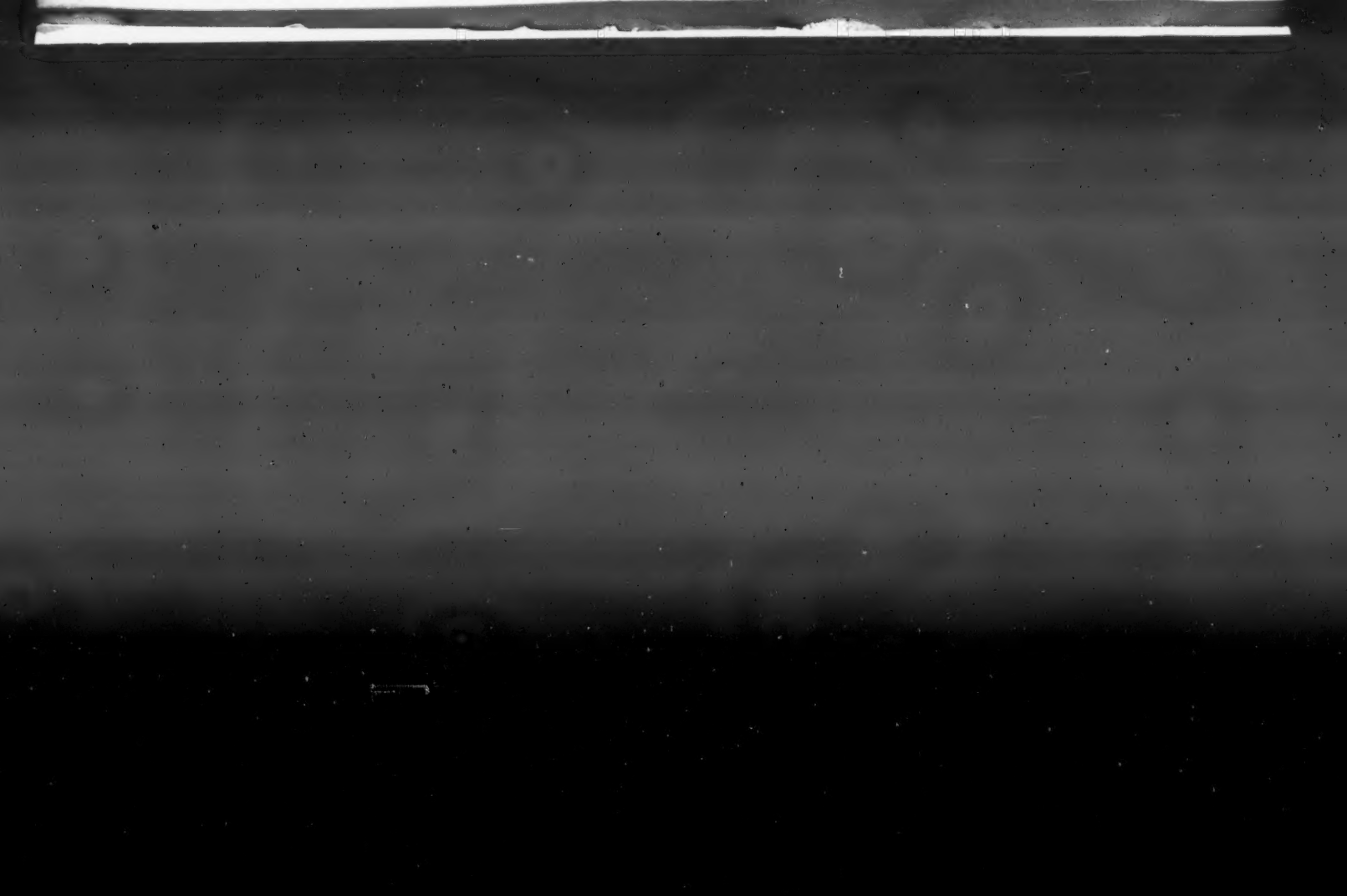

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ERRATUM.—Page 468, line 11 should read: difficultly soluble or insoluble, etc.